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Entomology in Malaria Control

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The importance of entomology in malaria control work has greatly increased in the past 4 years. This augmentation in itself is not surprising; the surprise lies in the fact that the value of entomology in malaria control has been virtually unrecognized for so long a time. As pointed out by Bradley (1944), the control of malaria involves three professions, medical, engineering, and entomological with the primary responsibility resting with the malariologist. For decades the malariologist and the engineer were the chief scientists concerned in the control of this disease. However, with the continued method of attack being vector control it became more apparent as time went on that a greater knowledge of mosquito biology and taxonomy must be secured. The duty of the entomologist is to supply this knowledge.

In 1937 a significant step was taken when the health departments of six southeastern states and Kentucky employed entomologists to work on malaria control. Williams (1940) reported that of the 16 states in the malaria belt at least 12 included an entomologist on the malaria control unit. The onset of the war found the value of entomology in disease control recognized by the armed forces although neither was fully aware of its usefulness. As the war progressed, however, utilization of entomologists increased until today full cognizance of their services is being made. Hardenbergh (1944) states that in the Army the greatest use of entomologists has been in malaria survey units. Bradley & Hanson (1943) point out the extensive use of entomologists on the Malaria Control Program in War Areas.

The foregoing paragraphs give a brief insight into the progress entomology has made in the field of malaria control during the past eight years. It is the purpose of this paper to discuss the functions of entomology in malaria control, giving examples of how these functions have been carried out on the program in North Carolina.

Entomology has two primary purposes in malaria control work:

1. To make anopheline density studies in areas to secure the necessary data for determining whether or not control measures are needed.
2. In areas under control to provide accurate information for the conduction of the larvicide and occasionally the drainage program. Under this phase the entomologists provide data to confine the control work to the specific species involved and to check on the effectiveness of control operations.

Darling's (1910) work in Panama of placing *Anopheles albimanus* as the chief malaria transmitter in that area led to the concept of "species sanitation"; the principle which underlies the first function. This function has served to prevent the initiation of control programs in many areas where such measures were unnecessary. In the southeastern states three species of anophelines, *Anopheles quadrimaculatus* Say, *A. crucians*, and *A. punctipennis*, are common; but the first named is the principal malaria transmitter. Consequently, the separation of these species has been required together with the usual distinction of anopheline and culicine genera.

To determine whether control measures are needed in an area the entomologist establishes a number of adult resting stations within a quarter-mile of the protected activity and visits these at regular one to three week intervals. The frequency of the visits depends upon the importance of the protected activity. Animal sheds are utilized exclusively for this work; only when this type is not available are culverts and other non-baited shelters used. In some cases one or two weekly visits will

reveal the need for control; at other times a month or more may elapse. When the *Anopheles quadrimaculatus* counts continue to remain low, the adult stations are checked throughout the season and usually for several years.

In 1942 the urgency for the control of malaria in the United States caused operations to start in numerous areas before from the protected activity. Results such as these clearly substantiated the 1942 decision to cease larvicidal operations. In 1944 three adult inspections revealed 10 *A. quadrimaculatus*. For the season of 1942 between $4000 and $5000 was expended in this zone; in 1943 the cost of one inspector amounted to approximately $500; in 1944 an expenditure of $15 to $20 was made.

Table 1.—Number of adult *Anopheles quadrimaculatus*, *A. crucians*, and *A. punctipennis* taken in catch stations in the Camp Sutton-Monroe zone in 1942, 1943, and 1944.

	Number Station Collections			*Anopheles* Species Taken				
				quadrimaculatus			*crucians*	*punctipennis*
	A[1]	BCD[1]	E[1]	A	BCD	E	ABCD	ABCD
1942 (6 visits)	12	21	0	8	16	—	2	20
1943 (19 visits)	342	49	16	40	13	72	1	68
1944 (3 visits)	25	0	3	10	0	10	0	4

Table 2. Number of substations positive for *Anopheles quadrimaculatus* and number of larvae of *A. quadrimaculatus*, *A. crucians*, and *A. punctipennis* taken in Camp Sutton-Monroe zone in 1942 and 1943.

	Number Substations Positive for *A. quadrimaculatus*		*Anopheles* Larvae Taken					
			quadrimaculatus		*crucians*		*punctipennis*	
	1942	1943	1942	1943	1942	1943	1942	1943
A band[1]	0	2	0	3	0	0	3	551
B band	0	6	0	15	0	1	15	147
C band	1	9	1	73	7	7	58	250
D band	1	0	1	0	0	3	47	236
	2	17	2	91	7	11	123	1184

it was possible to secure sufficient entomological data to determine the need for such work. In North Carolina the Camp Sutton-Monroe zone was under larvicide treatment in 1942, but the data (Tables 1 and 2, 1942) showed only a limited amount of *Anopheles quadrimaculatus* breeding, so operations ceased in 1943 except for the employment of a full-time inspector to make weekly larval and adult checks throughout the zone. The data obtained in 1943 (Tables 1 and 2) revealed that even without control measures *A. quadrimaculatus* production was too small to be significant. In both larval and adult stages *Anopheles punctipennis* was the prevalent species. In addition the majority of the *A. quadrimaculatus* larvae were collected half to three-quarters of a mile[1]

[1] Letters wherever used in article refer to distance station is from protected activity: A = zero to one-quarter mile; B = one-quarter to one-half mile; C = one-half to three-quarters mile; D = three-quarters to 1 mile; E = more than 1 mile.

In the period 1942 to 1944 full operation of 14 zones has been modified to the inspection of adult stations only. These changes indicate that the concept of "species sanitation" is a sound one and should be followed on all malaria control work. The practice of general mosquito control under the guise of malaria control is to be avoided since the latter phase only suffers in the eyes of the general public and budget commissions through such a coalition.

Control work preceding entomological studies is unsound since *Anopheles quadrimaculatus* potentialities are not evident through other means. The statement, " 'quads' are where you find them," is the only positive feature about *Anopheles quadrimaculatus*. Automobile diagnosis of *A. quadrimaculatus* breeding areas is a useless, expensive substitute for entomological data.

The second function of entomological service becomes active whenever it is deemed advisable by the first to conduct control operations. In this phase the work of the entomologist must be closely coordinated with that of the engineer since the latter is responsible for carrying on the control work. Fellton (1943) considers the entomologist as an "intelligence unit" serving the engineer. This simile fits very well.

In the present war situation it has not been possible to include an entomologist with each control unit in North Carolina. However, reliable individuals, preferably with two or more years of college work, after brief training periods have served very well as entomological inspectors. In practice one entomologist or inspector is placed in charge of the entomological work in two to five zones.[1] Under his supervision lesser qualified men are employed as "dippers" to test for breeding. The inspector visits the adult stations, supervises the "dippers," prepares all reports, identifies adult and occasionally larval specimens, and carries on larval inspection whenever necessary.

Each adult and larval station in a zone is given a number and a distance letter. Whole numbers assigned to a larval station serve only for the quick location of the corresponding substations on the map and not for designating water courses. Reference to a station number automatically includes all its substations. In the field each substation is marked by a small sign bearing the proper number.

The adult stations are visited weekly on the same day for a 10-minute sample. The organization and uses of these stations have been discussed (Schoof 1944). Generally, larval substations are visited routinely once every 8 days as long as no anopheline breeding occurs. Substations that show large anopheline larvae (third and fourth stages) are oiled and rechecked 24 to 38 hours later to test the effectiveness of the larvicide treatment. Substations with only small anopheline larvae (first and second stages) are rechecked 4 days later. Dippers work as a group in a map section so that oiling of positive substations the following day may be confined to one or two map sections. Such a procedure prevents the possible confusion on the part of the oiling crew brought about by spot oiling, and reduces travel time and expense. Slight variations from these methods occur in the different zones in the state, but the basis is essentially the same for all.

Larvicide treatment in each zone usually is on a selective basis, i.e., oiling or dusting only those substations where large anopheline larvae are found. In some zones, where *Anopheles quadrimaculatus* larvae are consistently taken at each inspection of certain larval stations, such stations are placed on a routine oiling schedule of 9–10 days, inspection being confined to the 24 to 48 hour check following treatment. It would be desirable to limit oiling to stations showing *A. quadrimaculatus* larvae rather than large anophelines were field identification possible by the inspector. Lack of equipment and highly trained personnel, however, make it necessary for larval specimens to be sent to a central office for determination, so that for safety, general anopheline control is practiced. As *A. quadrimaculatus* is less abundant than either *A. crucians* or *A. punctipennis* in many zones in North Carolina, the application of "species sanitation" to larvicide work is particularly desirable. An example of such control will be discussed later.

In a zone under control there is generally no necessity for having complete inspection over the entire area within one mile of the protected activity. The outer control bands (C & D) are usually given less consideration than the inner (A & B) ones since, unless blood meals are not available, *Anopheles quadrimaculatus* rarely flies in any great numbers more than a half-mile from its breeding place. Inspection work in the outer bands may be limited to adult stations or to semimonthly or monthly larval inspections. Frequently distribution of inspection work is upon the basis of map sections. Although the limits of any map section are artificial, such allocations of inspectional duties have been satisfactory.

The application of the points in the previous paragraphs can be illustrated by the Goldsboro zone as an example. In 1943 the 12 sections of the zone were on a routine basis of oiling every 10 days with inspection being chiefly a 48-hour check on oiling operations plus weekly visits to adult stations. The data from the 1943 program were analyzed and applied to

[1] A zone includes 5 to 60 square miles of control work.

Table 3.—Comparative larval and adult data on *Anopheles*. Goldsboro Zone 1943 and 1944 (May 1 to October 1).

	1943	1944
A. quadrimaculatus adults in A stations	120 (557)[1]	51 (434)
A. quadrimaculatus adults in BCD stations	652 (191)	109 (269)
A. quadrimaculatus adults in E stations	1250 (68)	1223 (50)
"Quad" positive larval substations	21	23
A. quadrimaculatus larvae taken	47	38
A. crucians larvae taken	113	104
A. punctipennis larvae taken	200	848
A. crucians adults taken in ABCD stations	512	216
A. punctipennis adults taken in ABCD stations	212	223

[1] Figures in parentheses refer to number of collections made.

operations for 1944; the principal recommendations being to place the entire zone on selective oiling, to concentrate work in sections A-2, B-3, and B-4, and to curtail larval inspection in Section B-1 using weekly visits to the adult stations as a check. This plan was carried out, further modifications being made as the season progressed; *e.g.*, larval inspection in A-1 ceased in 12 of the 23 stations after August 22.

A comparison of the results for 1943 and 1944 (Table 3) shows that the recommendations were sound; *Anopheles quadrimaculatus* adult densities in 1944 in the "A" stations being less than in 1943. Counts in stations in this control band are the only true indices to the effectiveness of a control program. Densities in the "BCD" stations also were lower in 1944 than in 1943. The check stations in the "E" area, however, contained approximately the same densities for both years indicating that the natural abundance of the species was similar. Section B-4 was dropped from the control area early in 1944; but as its inclusion in 1943 occurred late in the season and since it contained no "A" adult stations, the reduction had little effect upon the data. An insignificant decrease in area also took place in Section C-3.

In 1943, 5359 gallons of oil were used in the Goldsboro zone; in 1944 the amount dropped to 233 gallons, a saving of 5126 gallons or $492.10. If the cost of applying this oil is estimated at 75 cents per gallon, a total saving of $4336.60 has been effected. Almost 100 per cent of this saving was due to selective oiling as other control measures (drainage) were at a minimum during this period.

This same type of saving has occurred in the other seventeen zones of the state since 1942. Factors such as drainage, weather conditions, and reduction in control area have led to reduced oil consumption in successive years, but drastic decreases have been made by selective oiling.

At the Fort Bragg Zone in 1944 the concept of species sanitation was strictly practiced, oiling being carried out only at those substations where *Anopheles quadrimaculatus* was taken. The results in 1943 indicated the need for such a move, and the comparative entomological data for the two years (Table 4) reveal the soundness of the step. No separate figures for oil

Table 4.—Comparative larval and adult data on *Anopheles*. Fort Bragg zone 1943 and 1944 (May 1 to October 1).

	1943	1944
A. quadrimaculatus adults in A stations	9 (107)[1]	19 (160)
A. quadrimaculatus adults in BCD stations	17 (73)	7 (127)
A. quadrimaculatus adults in E stations	2 (13)	344 (20)
"Quad" positive larval substations	0	2
A. quadrimaculatus larvae taken	0	2
A. crucians crucians larvae taken	107	538
A. crucians georgianus larvae taken	71	570
A. punctipennis larvae taken	49	281
A. crucians adults taken in ABCD stations	263	369
A. punctipennis adults taken in ABCD stations	222	474

[1] Figures in parentheses refer to number of collections mad[illegible].

consumption in this zone are available; the only ones secured applied to both the Fort Bragg and Fayetteville zones. Consideration of these combined figures for the two years shows a reduction from 13,673 gallons in 1943 to 1496 in 1944, a saving of 12,177 gallons. As conditions in the Fayetteville zone were essentially the same both years, approximately 90 per cent of the reduction occurred in the Fort Bragg zone. Thus a saving of $1095.93 was effected in oil consumption alone. Cost of application of this oil at 50 cents per gallon[1] would amount to $5479.65, a total saving of $6575.58 being made possible through "species sanitation."

A considerable reduction in oil consumption in the state has been brought about by the delay of oiling in the spring until data definitely show that *Anopheles quadrimaculatus* production has begun. Scattered slight breedings at this time are ignored. In 1942 general oiling commenced around April 15; in 1943 and 1944 with entomological data it was not necessary to oil until May 20 and June 1. One zone had little *A. quadrimaculatus* breeding until mid-August in 1944, whereas in 1943 such breeding occurred in June.

The functioning of entomology in malaria control has also led to increased efficiency of operations, a contribution which is probably of greater significance than the benefits derived from the reduction in larvicide measures and control projects. Malaria control is now on a scientific basis; the phrase "anopheline densities" has replaced "gallons of larvicide used" as the criterion of the effectiveness of operations.

It is to be emphasized that there is no stereotyped plan of operation in the coordination of control and inspection phases. Different zones of operation may require different interpretation of similar data, *i.e.* large swamps in certain sections of the state require extensive control, heavy breeding of *Anopheles quadrimaculatus* occurring therein; in other regions such swamps have little *A. quadrimaculatus* breeding, *A. crucians* being the prevalent species. In addition, the year to year variation in ecological conditions bring about operational changes in the same zone. The problem being fluid requires control of a similar nature.

[1] The difference in application cost for Goldsboro and Fort Bragg is due to variation in types of water courses in each zone.

As has been illustrated in foregoing material, the application of entomological practices to malaria control has led to increased efficiency of such work and at the same time reduced the amount of expenditures. It is the opinion of the writer that so long as the principal method of the suppression of malaria is by the control of the vector, the problem is primarily an entomological one. Therefore, larvicide treatment should be carried out under entomological supervision since for efficient, economical work in this phase, a person thus trained is far more able to interpret accurately the biological aspects of the problem in relation to control operations.

Major drainage and other methods of water elimination on the other hand call for engineering skill. Such work, however, should be based upon entomological findings.

The aforementioned control organization is contrary to the usual field operations of malaria control where the engineer supervises both larvicidal and drainage work, the entomologist being concerned only with the collection of data for use by the engineer. Although the writer believes entomological supervision of larvicide work is the best means of efficient, economical operation, it has been evident to him that today many entomologists do or will not recognize that malaria control is chiefly a practical problem. Fellton (1943) points out that the entomologist must overcome his instinct for research and realize that investigation of extraneous details in regard to the problem, no matter how interesting, are of strictly secondary importance. This criticism is valid and has in many cases effectively barred the entomologist from active supervision of larvicide work. Until entomological workers align themselves along the practical axis of malaria control they cannot hold the position which is open to them. Research is a vital part of malaria control; but when included in field applications at the expense of the latter, both aspects suffer. Scientific research must be planned; conclusions based on "miscellaneous" field data lead only to faulty recommendations.

The future of the entomologist in malaria control work is promising, particularly if adaptation is made toward the practicality of the problem.—3-12-45.

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Insect Damage to Nylon

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Substantiated reports of damage to finished nylon hosiery in the shipping room of a New York finishing mill caused by the larvae of one or more species of carpet beetle led to a series of studies and an attempt to isolate the factors which give rise to the attractiveness of nylon to these insects.

The insects used for testing included *Anthrenus verbasci* (Linn.); *Anthrenus vorax* Waterhouse; *Attagenus piceus* Olivier; and the webbing clothes moth. *Tineola bisselliella* Hummel. *Anthrenus verbasci* proved itself to be the most serious pest to fabrics of this type but feeding damage was observed with each species.

MATERIALS AND METHODS.—Experimental work with nylon consisted of a series of feeding tests in which the factors of preference position of the materials in the culture containers and the nature of treatment given the materials were observed. Additional work on olfactory response and respiratory quotients was attempted.

For feeding experiments samples of the variously treated fabrics were placed between pieces of thin cardboard so that an area of 2.25 square centimeters was exposed. The samples so prepared were placed in metal containers according to a definite pattern and incubated at 28° C. with from one to 20 larvae. The duration of the feeding tests was from 1 to 4 weeks. Individual containers were checked every other day and the amount of damage was estimated by the number of feeding holes observed. Records were kept photographically.

Olfactometry tests were attempted using a specially constructed olfactometer which satisfied the criteria for such an instrument as set up by Hoskins & Craig (1934).

Respiratory quotients were calculated from data obtained using a battery of *Fenn* respirometers equipped with side arms containing conductivity electrodes. With this type of instrument it is possible to measure the carbon dioxide liberated by the organism as well as the oxygen consumed.

Fabrics tested included finished nylon from old hosiery derived from many sources; new finished nylon; unfinished but knitted nylon; a rough cloth woven from sized nylon yarn; a fabric woven from dry nylon; cotton muslin; and cotton gauze.

Finishing materials included a polyvinal alcohol size; and scours including two sulfonated oils and a sulfated alcohol. These materials were used according to the commercially practiced procedures.

RESULTS.—From preference tests with samples of finished nylon of unknown pre-treatment as compared to samples of a brown wool cloth upon which the cultures were reared it was demonstrated that the active larvae of *Anthrenus verbasci* preferred nylon. In these tests one larva was placed in a container with a sample of wool and a sample of nylon.

[1] From the Laboratory of Insect Physiology, Cornell University, Ithaca, N. Y.

[2] Acknowledgement is made to Dr. Grace Griswold of Cornell University for her assistance and advice in handling the test insects; and to the Merrill Hosiery Co. of Hornell, N. Y., the Duffy Silk Co. of Buffalo, N. Y., and the E. I. duPont de Nemours Co. of Wilmington, Delaware for their assistance in furnishing various of the materials used in the experimental work.

The chance of contact was equal for each. After 10 days exposure it was observed that of 12 larvae, only six had fed. These had made 45 holes in the nylon samples and no visible feeding was observed on the wool. Of the six larvae which did not feed; two died, one moulted, and one pupated.

Subsequent feeding tests demonstrated that the position of the test materials with respect to others in the same container made no difference in the feeding of the larvae upon the material of their choice.

In a starvation test which was carried out under conditions similar to those which might be expected in a storage warehouse, one larva made 40 holes in a piece of clean nylon 2 inches square during an exposure of 10 days. This gives an indication of the potential danger of this insect to these fabrics.

Further tests with various fabrics which had been subjected to several degrees of processing showed that the scoured nylon was definitely more attractive than the dry nylon or the sized nylon. Samples of cotton cloth treated in the same way showed the same results. Of the three scours tested, the first scour which contained a sulfonated oil and sodium silicate imparted the greatest attraction, the sulfated alcohol which is both a scour and a finishing agent gave the next degree of attraction, and the third scour which was a sulfonated oil (different from the first) showed the least attraction.

Olfactometry tests showed no indication whatsoever that these insects respond to olfactory stimulation in the search for food.

The respiratory quotient measurements were too erratic to be of value in the estimation of the nature of the food being metabolized by the insects.

Microscopic examination of the foecal pellets from larvae reared upon nylon showed short sections of the material which appeared to be intact. In some cases slight indentations were noticeable upon the surface and in most instances the fibers appeared to about 0.02 mm. greater in diameter than the uneaten fibers. Examination of the digestive tracts of larvae which had been exposed to dry nylon was made using gross dissection, frozen section, and fixed sections. In one doubtful case it appeared that the insect had nibbled slightly at the material. No damage was observed on any fabric woven from dry nylon.

CONCLUSIONS.—Nylon which is finished completely or which has been finished through the scouring process is very susceptible to damage by the larvae of several species of carpet beetles, and especially those of *Anthrenus verbasci*. The important factor in the attractiveness is not connected with olfactory stimulation. The larvae do not digest the eaten nylon although it is conceivable that they could acquire a small amount of nutritive value from it. From observations made it appears that the tactile senses of the insect are of great importance in their selection of food, therefore, the finish imparted to the fiber is probably the critical factor.

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PROCEEDINGS SOUTHERN WAR CONFERENCES

The Proceedings of The First and Second War Conferences on Entomology are now available. The proceedings of the First Conference are mimeographed, while the proceedings of the Second War Conference are printed by the lithograph process (Multilith offset).

Contents of the First War Conference proceedings follow:—A. Symposia; Cotton Insect Control; Control of Pests Affecting Health and Comfort of Man and Domestic Animals; Fruit Insect Control; Insecticides and Machinery; Control of Pests of Commercial Vegetables and Victory Gardens: The Control of Pests of Field Crops and Stored Grain and Seeds. B. Presidental address. C. Technical paper.

Contents of the Second War Conference proceedings follow:—A. Symposia; DDT; Cooperation Between Members of The Agricultural Insecticide Industry and Professional Entomologists of The South; Post War Planning For Southern Entomology. B. Presidential address. C. Technical papers.

For copies forward orders to John T. Creighton, College of Agriculture, University of Florida, Gainesville. Price $1.25 each.

Some Dinitrophenol Derivatives as Mosquito Larvicides[1]

H. I. Magy and W. M. Hoskins

The dinitrophenol group of compounds has attracted considerable interest among entomologists for several years and certain members of the group have become established as commercial insecticides. However, little attention appears to have been given to their possible use as mosquito ovicides and larvicides. In a laboratory investigation with third and fourth instar larvae of *Culex pipiens* L., *C. territans* Walk and *C. quinquefasciatus* Say, Campbell *et al.* (1934) found 3,5 dinitro-*o*-cresol to kill all larvae in 24 hours at a concentration in water of 1:10,000, some of the material being present as solid particles. At 1:40,000 less than 50 per cent were killed.

Materials and Procedures.—Three compounds were tested, namely, 3,5 dinitro-*o*-cresol (DNOC), 2,4 dinitro-*o*-cyclohexyl phenol (DNOCHP) and the dicyclohexyl amine salt of the latter compound (DCA-DNOCHP), hereafter, for convenience, referred to by the letters in parenthesis. Both Eastman's pure 3,5 dinitro-*o*-cresol and a sample prepared by fractional crystallization from a commercial material were used with no appreciable difference in results. The other two compounds were prepared in a similar manner from commercial products. In the experiments with solutions the latter was prepared warm at higher concentration than desired and then cooled, filtered and diluted to exact concentration for use with care that no particles were present. When it was desired that particles should be present, the solutions were prepared as above at the desired concentrations and the necessary amount of a strong solution in acetone (never over one cc.) was added just before the larvae were introduced. The dinitro compound was thrown out of solution in acetone as very fine particles and thus opportunity was given for the larvae to swallow particles of the substance. Except when added to saturated solutions these particles, of course, gradually passed into solution, but this is a slow process at ordinary temperature and some solid remained at the conclusion of each such test. Separate experiments showed that the amounts of acetone introduced are without effect upon the larvae either with or without the presence of a dinitro compound.

In the case of solutions in which undissolved dinitro compounds were also present in suspension, the concentration of dissolved material was determined by carefully filtering out the solid particles, making the filtrate alkaline and comparing the color developed with that in solutions of known concentration according to the procedure of Boyce *et al.* (1939). The total dinitro compound added less that in solution gave the amount left in suspension.

All pH values of water samples and solutions were determined by use of a glass electrode and Coleman electrometer. For determination of the pH of the gut contents of mosquito larvae a number of late third and early fourth instar larvae were placed in beakers each containing a dilute solution of one of five indicators (bromcresol purple, bromthymol blue, phenol red, cresol red and thymol blue) chosen to cover the range from pH 5.4 to 9.6. The colors assumed by the indicators, which may be observed easily by turning the larvae upon their backs, indicate the pH of the various regions of the digestive tract.

Eggs of the mosquito *Culiseta incidens* (Thomson) were collected from Strawberry Creek, which runs through the University campus, and placed in beakers containing the same water and a pinch of dried brewers' yeast. Hatching and growth were normal and mortality low. For toxicity tests larvae were used in the first and fourth instars and a few ovicidal tests were made. A small pinch of dried brewers' yeast was added to all test solutions which were kept at laboratory temperature, usually within the range 20–23° C. Counts of dead and moribund larvae were made at the end of 24 and 48 hours. At the end of the latter period the surviving larvae were removed to creek water with a pinch of dried brewers' yeast added and observations were made at intervals thereafter. Forty eight hours

[1] Contribution from the laboratory of insect physiology and toxicology, Division of Entomology and Parasitology, University of California.

was chosen arbitrarily as the total length of exposure on the assumption that in practical control work an application of chemical could not be expected to last longer than that period on account of movement of water, reaction with solutes or suspended matter, etc.

It was shown by Boyce *et al.* (1939) that the solubility of DNOCHP in aqueous solutions increases markedly as the pH rises. Preliminary tests made during the present work showed that this same condition prevails with DNOC and DCA-DNOCHP also. Hence with alkaline waters fine particles, *e.g.* those in a dust, dissolve more rapidly than in the case of acidic waters. In either case, of course, the process is hastened by rise in temperature. In order to determine what would happen in a practical case an excess of finely ground DNOCHP and of DCA-CNOCHP was added to samples of Strawberry Creek water (pH 7.3) and kept with occasional shaking at its natural summer temperature for about 12 hours. The amounts in solution then were 131 mg. per liter for DNOCHP and 82 mg. per liter for its DCA salt. These values are about one third the total solubility for the pH concerned as determined after prolonged soaking of the compounds. DNOC is very much more soluble, reaching about 4 grams per liter in the same water if sufficient alkali is added to maintain the pH.

Limited field trials were made near Modesto in the San Joaquin valley with DNOCHP and DCA-DNOCHP as dusts. The former was used at 1, 3, 5, 10, 12.5 and 50 per cent and was applied with a *Root* hand duster in the grass and weeds growing along the edge of an irrigating ditch at the approximate rate of 50 pounds per acre. The water at the center of the ditch was flowing about two miles per hour. DCA-DNOCHP was used in the form of a commercial dust at 40 per cent concentration. Counts were made of larvae of the mosquito *Anopheles maculipennis* sub. sp. before treatment and 24 hours later by making 30 dips with a quart sampler at random in the treated areas.

RESULTS.—No ovicidal action was found when eggs of *Culiseta incidens* floated for as long as 3 days before hatching upon solutions containing up to 126 mg. per liter DNOC or DNOCHP or up to 82 mg. per liter DCA-DNOCHP. The mortalities of first instar larvae at the end of 48 hours are shown in figure 1. It is obvious that DNOC has but little effect at any reasonable concentration and that the other two compounds become effective only when the concentration approaches 100 mg. per liter (100 ppm). With DNOCHP the maximum kill was

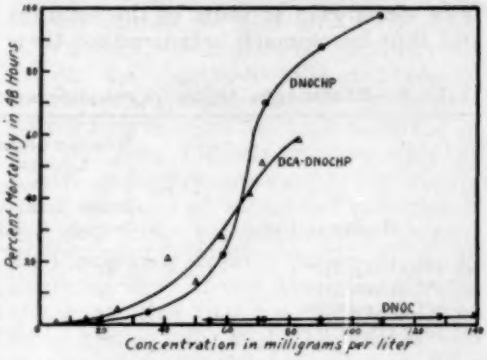

FIG. 1.—Toxicity of aqueous solutions of dinitrophenol compounds to first instar larvae of *Culiseta incidens*.

obtained within 24 hours in the higher concentration range but more slowly in the more dilute solutions. The action of DCA-DNOCHP was slower at all concentrations.

The above experiments were then repeated with early fourth instar larvae and resulted in low mortalities with each compound in solution. Strikingly different results were obtained, however, when the larvae were put into solutions containing relatively small amounts of suspended particles of the compounds, as shown in table 1.

Table 1.—Mortality of fourth instar larvae of *Culiseta incidens* exposed to solutions of certain dinitro compounds containing suspended particles.

COMPOUND	CONCENTRATION In solution	CONCENTRATION In suspension	MORTALITY 2 hours	MORTALITY 24 hours
	mg. per liter	*mg. per liter*		
DNOCHP	82	7.5	100	
DCA-DNOCHP	96	4.4	28	81
	95	15.4	82	94

It is obvious that whereas these compounds have very little contact toxicity to *C. incidens* larvae, they are highly toxic when swallowed. A similar test of DNOC

as a stomach poison for mosquito larvae is practically impossible because of its high solubility. The use of stronger solutions in order to make it possible for suspended particles of DNOC to persist longer is not feasible because the solutions themselves become toxic, *e. g.*, in one containing 280 mg. per liter the mortality was 95 per cent within two hours. This high kill may have resulted at least in part from swallowing of some of the solution and thus be stomach action rather than had dissolved, but enough remained at the surface or in suspension to kill all the larvae within a few hours.

Since ingested particles must dissolve, at least in part, before they can be absorbed and have a toxic effect it seemed worthwhile to determine the pH of the digestive tract contents of the *Culiseta incidens* larvae. The five indicators used as described earlier agreed in showing the foregut and cardiac region of the midgut of fourth instar larvae to be alkaline, pH

Table 2.—Effects upon *Anopheles maculipennis* sub. sp. larvae of dusting edge of irrigating ditch.

Material Used	Number of Live Larvae		Observations
	Before dusting	24 hours later	
(a) 1% DNOCHP[1]	47	7	no dead predators; no visible residue
(b) 3% DNOCHP[1]	42	3	1 dead tadpole; 1 dead fish; no visible residue
(c) 5% DNOCHP[1]	64	3	no predators seen; no visible residue
(d) 10% DNOCHP[2]	45	0	several dead Odonata and mayfly larvae; visible residue
(e) 12½% DNOCHP[1*]	36	0	several live predators; 1 dead tadpole; visible residue
(f) 50% DNOCHP[1]	40	0	several dead predators; visible residue
(g) 50% DNOCHP plus 2½% heavy oil[3]	57	0	several dead predators; visible residue
(h) 40% DCA-DNOCHP[1*]	67	0	no dead predators seen; no visible residue
(i) 120 feet downstream from (h)	32	41	no dead predators seen; no visible residue
(j) check	47	15[4]	

[1] Proprietary mixtures, made by spraying a solution of DNOCHP or DCA-DNOCHP in a volatile solvent upon the carrier.
[2] Made in laboratory by grinding DNOCHP with frianite.
[3] Made in laboratory by grinding together the DNOCHP, oil and frianite.
[4] An overnight rise in the water level with increased flow probably accounts for the decrease in number of larvae.
[*] Contained a wetting agent.

contact. The integument thus appears to be relatively impermeable to these compounds. Practical use of such a high concentration would doubtless be limited to water in small pools and artificial containers.

It might be expected that application of dinitro compounds as dusts would result in longer persistence of the particles since they would tend to remain at the surface of the water for a time. To test this point a dust consisting of a proprietary mechanical mixture of 40 per cent DNOCHP in an inert carrier was put upon the surface of Strawberry Creek water taken to the laboratory at a rate approximating 40 pounds per acre. The volume concentration corresponded to 17.5 mgs. per liter. Twenty-four hours later first instar *Culiseta incidens* and *Anopheles maculipennis* sub. sp. larvae were added. Since the water was slightly colored some of the compound obviously

approximately 8.5. Proceeding along the gut the pH decreases to about 7.4 in the sixth abdominal segment. At the point where the Malphigian tubes enter (between the sixth and seventh abdominal segments) there is a marked fall in pH to less than 6.0 which then rises somewhat toward the rear end of the gut. The absorptive region of the digestive tract is thus sufficiently alkaline to ensure solution of ingested particles of the dinitro compounds and in fact observation of the opened gut of larvae dying from ingestion of DNOCHP or DCA-DNOCHP always showed many particles in the foregut but none visible in posterior regions.

The results obtained in field trials against *Anopheles maculipennis* sub. sp. in an irrigating ditch are shown in table 2. Rate of application at edge of ditch was approximately 50 pounds dust per acre.

It is evident from the above data that the most dilute dust giving satisfactory

results was that containing 10 per cent DNOCHP. Addition of oil, which might be expected to decrease rate of solution and hence prolong activity, had no apparent effect. Toxicity to various predators is a serious objection to this material. The 40 per cent DCA-DNOCHP dust was equally effective against the mosquito larvae and no harm to predators was noticed. The relatively large amount of wetting agent in this material may account for its disappearance with the 24 hour period. Unfortunately, opportunity was not afforded for trials either at lower amounts per acre or with less wetting agent.

DISCUSSION.—The strong yellow color of the dinitro compounds, especially in alkaline solution, is an objection to their use. Hence the less soluble ones will be preferable, provided toxicity is still exerted after ingestion by the larvae. A study of numerous available compounds of this family as larvicides would be well worth while. Another method for reducing rate of solution and hence for prolonging activity toward larvae is the use of larger particles. This has two limitations which have often been encountered with other larvicides such as paris green, namely, rapid settling to the bottom of the treated body of water so that the particles are lost in the debris, and secondly, inability of the larvae to swallow the larger particles. Observation of first instar *A. maculipennis* sub. sp. larvae indicated that the distance between the inner lateral edges of their mouth brushes is at least 20 microns, which is greater than the diameter of about half the particles in one commercial 40 per cent DNOCHP dust.

SUMMARY.—Solutions of 3,5 dinitro-*o*-cresol, 2,4 dinitro-6-cyclohexyl phenol or dicyclohexylamine salt of 2,4 dinitro-6-cyclohexyl phenol are toxic to larvae of the mosquito *Culiseta incidens* only at relatively high concentrations but if only small amounts of suspended particles of the two latter compounds are present, high mortality results within 24 to 48 hours or less. Hence they function as stomach rather than as contact poisons. Field trials with dusts applied in the weeds and reeds along an irrigating ditch gave high kill of *Anopheles maculipennis* sub. sp. larvae with dusts containing 10 per cent 2,4 dinitro-6-cyclohexyl phenol or 40 per cent of the dicyclohexylamine salt each applied at rate of 50 pounds to the acre.—3-5-45.

LITERATURE CITED

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"JOHN SCOTT AWARD" TO GOODHUE AND SULLIVAN

Most readers of the JOURNAL will have learned Lyle D. Goodhue and Captain Wm. N. Sullivan, Jr., through their pioneer work in the development of aerosols and the perfection of the aerosol bomb.

The award is made from a special fund established by one John Scott, a native of Edinburgh, Scotland, and administered by the City of Philadelphia. It carries, in addition to the honor, a monetary award of $1,000.00. The list of recipients, in the past, of this award includes such distinguished names as Thomas A. Edison and Madame Curie.

The presentation was the main event of a dinner given in honor of the winners of the award. The event took place in Philadelphia and was attended by several entomologists representing the Bureau of Entomology and Plant Quarantine and others, including former teachers of the two men.

The Transport of Insects in Aircraft

CAPT. V. G. DETHIER

For approximately 2 years a study has been conducted in Central Africa by the Army to determine the number and kinds of insects inadvertently transported by aircraft, the various factors affecting the number, variety, viability, and behavior of these insects, and methods of control. The latter phase has been variously reported in the literature and in divers official reports.

The results and observations reported herein are based upon collections made in Central Africa from December 1943 to April 1945 inclusive. Determinations were made by members of the United States National Museum through the agency of the Army Medical Museum at Washington, D. C.

METHODS.—Live insects gain entry to aircraft by two means when a plane is grounded. They enter by their own locomotion or ensconced in cargo or on passengers. There is no evidence from these studies that successful entry may be accomplished through chance encounter during flight.

In general there are three compartments of importance in which insects may travel: in the fuselage, within wing and tail spaces, and in engine nacelles. Irrespective of the type of plane admission to the fuselage is gained while a plane is parked. During this considerable period, both day and night, at least one entrance is habitually left open and more often one or more doors, hatches, or windows. In models with fully retractible landing gear the engine nacelles into which gear retract are open while the plane is parked as well as during landing and take-off. In flight they are closed. Entry to spaces beneath wing and tail surfaces may be effected through relatively large openings associated with ailerons, flaps, and trim tabs.

Specimens were collected from the interiors of parked planes at various points between India and the west coast of Africa by especially trained personnel. Collections were usually made immediately after arrival and, when feasible, prior to removal of freight. Inasmuch as all arriving planes were sprayed prior to landing the insects collected were invariably dead or dying. Engine nacelles were searched at the same time. The sole opportunities for complete examination of wing and tail spaces presented themselves during major maintenance operations; consequently, of the three sources of information this is the most meager. Studies of the behavior of live insects present in planes during flight are based upon observations made during an average of twenty flying hours per month.

All observations and specimens were taken on 11 types of aircraft of which 6 were combat and 5 transport.

INSECTS IN THE FUSELAGE.—For purposes of the present discussion a grounded aircraft may be considered as similar to a building. Within either one and subject to the conditions enumerated below there will be found representatives of those species which abound in the vicinity. A plane differs from a building chiefly in that it changes its locality periodically; however, the route over which these planes fly supports a surprisingly uniform and continuous arthropod fauna. In this case geographical locality as a factor affecting the sampling of species is very nearly a constant. At most it is one of the minor factors. On the other hand, the four most important factors influencing the selection and comparative number of species are: (1) the habits of the insect, (2) the immediate environment in which the plane is parked, (3) the ratio of population density of each species in this particular environment to the total population, and (4) the season.

Some insects are by nature more domestically inclined than others. Thus one would expect to find *Musca sorbens*, *Camponotus spp.* and *Anopheles gambiae* in greater numbers than wilder species. Insects in the former category may be said to enter planes more or less by design while the entry of others is of a more accidental nature. Then too, strong fliers, far ranging winged species, and ubiquitous wingless species, especially ants, are to be expected.

At some points planes may be parked as far as 2 miles from the nearest vegetation, in the midst of an expanse of macadem, blacktop, concrete, or gravel. At other points they may be parked in fields, on the

fringe of jungle, or in close proximity to some water course. In the first instance there will be a preponderance of flies and other strong fliers; in the second, mostly Cicadellidae and Orthoptera; in the third, shade loving species, especially Culicidae; in the last, aquatic species.

If the first two factors are favorable to a given number of species to an approximately equal degree, the ratio of numerical abundance of each species to the natural population will determine the ratios of catches within the plane. This explains, for example, the outstanding number of *Musca sorbens* captured at some points.

Finally, seasonal fluctuations in the insect fauna constitute a most important factor. At one field *Simulium griseicollis* becomes extremely abundant during the month of December only to disappear completely in August. It is not surprising then to discover this species in aircraft in quantity during winter months. The migratory locust, on the other hand, swarms in August with a consequent increase in plane-catches at that time.

Because of the diversity of cargo transported over the route studied an added variety of species gains access to aircraft via the cargo. Thus, crickets enter with wicker furniture and cargo containers, ticks with goats, ants and earwigs with personal baggage, stored grain pests with grain, and fleas and lice with passengers.

In evaluating the results of collections from aircraft each of these factors must be taken into consideration.

SPECIES COLLECTED.—During this study 816 samples were taken. These comprised approximately 2006 insects, a minimum of 210 species (some specimens were too badly damaged to permit of specific identification), 86 families, and 13 orders (Table 1). Diptera constituted 88.5 per cent of the total catch and one species alone, *Musca sorbens*, accounted for 45.9 per cent of all insects caught. This was to be expected in view of the preponderance of muscoid flies in the savannah country through which must of the route runs and in view of the domesticity of this species. Of remaining Diptera very few were Culicidae. Their being in the minority might have been due in part to the fact that all airfields are so-called sanitated areas as far as mosquitoes are concerned. During the blackfly months (December to February) in the Sudan it was expected that Simuliidae would constitute an overwhelming majority of the insects captured in planes in this area. To the contrary, although specimens of the common species, *Simulium griseicollis*, were taken in quantity, the number was not so great as was to be expected from the density of the indigenous population. During the sandfly months of March to September in the same area not a single specimen of *Phlebotomus* was taken. It is felt that the distance of airstrips from breeding areas coupled with the limited flight range of this fly accounted for its absence.

Hemiptera and Homoptera, comprising the second largest group, were represented chiefly by Cicadellidae. This is not unusual since at certain times of the year, especially in the summer months, these insects occur in enormous numbers.

Among the remaining species there were no insects of especial medical or agricultural importance.

INSECTS IN NACELLES.—At no time were insects recovered from nacelles. This is no indication, however, that they may not travel in this section. If they do, chances are that they would make good their escape upon landing.

To test the ability of insects to survive flights in this hot, dusty, and oily compartment a series of experiments was conducted in which caged mosquitoes were placed in nacelles and subjected to routine flights. In each test a simple cubical cage of ordinary screening material, four inches on a side, was fastened in a protected corner of the compartment. Each cage contained 10 mosquitoes, usually *Anopheles gambiae*, which had been reared in the laboratory. After routine flights ranging in duration from 15 minutes to 4 hours the cages were removed for examination. In only one test out of a hundred were insects recovered alive. The plane in this case possessed fully retractible gear. The mosquitoes were so badly battered, however, that all died within an hour. There was no indication from these experiments that variation either in the duration of flight or the type of nacelle significantly affected the ability to survive. Subsequent experiments showed that the insects were killed during take-off.

INSECTS IN WING AND TAIL SPACES.—Examinations of the interior spaces of dismantled and wrecked wing and tail sur-

faces resulted in the discovery of one species only, *Musca sorbens*. It is hardly surprising that some found their way into these spaces. Once inside there was little likelihood of the insects ever escaping on account of the structural maze of supports which successfully defeats even phototaxis by obstructing the ingress of light.

BEHAVIOR OF INSECTS DURING FLIGHT.—Routine flights along this route were made at altitudes below 14,000 feet. The partial pressure of oxygen was therefore not a striking factor. Temperature changes produced more profound, though transsient, effects identical with those experienced on the ground. As the temperature dropped insects became quiescent, coming to rest usually in corners and crevices. Upon descent with a consequent rise in temperature they resumed normal activity. During flight, flying species tended to congregate against windows and in the navigator's dome in response to light. At the termination of a flight, when

Table 1.—Summary of the families of insects collected in aircraft in Central Africa from December 1943 to April 1945.

ORDER AND FAMILY	NUMBER TAKEN	PER CENT OF TOTAL
DIPTERA		88.5
Muscidae	1246	
Agromyzidae	141	
Drosophilidae	69	
Chloropidae	63	
Otitidae	34	
Sarcophagidae	30	
Phoridae	27	
Calliphoridae	25	
Anthomyidae	25	
Simuliidae	21	
Dolichopodidae	16	
Empididae	14	
Lonchaeidae	11	
Culicidae	10	
Tendipedidae	7	
Larvaevoridae	6	
Stratiomyiidae	6	
Cypselidae	5	
Ephydridae	4	
Sepsidae	3	
Sapromyzidae	2	
Itonidae	2	
Tyledidae	1	
Conopidae	1	
Tabanidae	1	
Bombyliidae	1	
Fungivoridae	1	
Omphralidae	1	
Trypetidae	1	
Diopsidae	1	
Chironomidae	1	
HEMIPTERA-HOMOPTERA		3.1
Cicadellidae	21	
Pentatomidae	10	
Miridae	7	
Lygaeidae	7	
Aphidiidae	3	
Anthocoridae	3	
Araeopidae	3	
Cixiidae	2	
Cydnidae	1	
Achilidae	1	
Coreidae	1	
Coptosomatidae	1	
Corixidae	1	
Gerridae	1	

Table 1.—*Continued*

ORDER AND FAMILY	NUMBER TAKEN	PER CENT OF TOTAL
HYMENOPTERA		3.0
Formicidae	26	
Chalcididae	11	
Braconidae	8	
Megachilidae	5	
Vespidae	4	
Sphecidae	2	
Chrysididae	2	
Bethylidae	1	
Apidae	1	
COLEOPTERA		2.8
Anthicidae	14	
Chrysomelidae	9	
Coccinellidae	4	
Tenebrionidae	4	
Cerambycidae	4	
Bostrichidae	3	
Curculionidae	2	
Carabidae	2	
Histeridae	2	
Pselaphidae	2	
Hydrophilidae	2	
Lyctidae	2	
Colydiidae	1	
Scarabaeidae	1	
Bruchidae	1	
Cyphonidae	1	
Anthribidae	1	
Cryptophagidae	1	
ORTHOPTERA	1.45	
Acrididae	15	
Gryllidae	6	
Blattidae	6	
Tettigoniidae	1	
Mantidae	1	
LEPIDOPTERA		0.60
Noctuidae	10	
Amatidae	1	
Gelechiidae	1	
DERMAPTERA	6	0.30
CORRODENTIA	1	0.05
NEUROPTERA		0.05
Chrysopidae	1	
TRICHOPTERA	1	0.05
ODONATA	1	0.05
THYSANOPTERA	1	0.05

windows were opened to alleviate heat distress, the insects so congregated readily made their escape. No superficial untoward effects traceable to engine noise and vibration were noted.

DISCUSSION AND SUMMARY.—There is no indication whatsoever from this study that aerial insect fauna gains entry to aircraft during flight. Airflow and slipstream are such that most are directed away from the plane. On the ground the majority of species are found in the cabin because this possesses larger ports of entry, is more conducive to the well-being of organisms, and contains odors associated with food and human habitation. Due to the small number of opportunities for insects to enter and survive in wing and tail spaces it is felt that these spaces are of minor importance in any control program. Although there is one instance of a caged insect having survived in the nacelle of a certain type of aircraft, it is unlikely that insects would normally enter nacelles, or, having entered, remain there, because the dust, oil, and grease in that compartment exert some repellent effect. The chief concern regarding control is, therefore, the cabin. On the basis of the collections made in Africa it is concluded that practically any species of insect may be found in planes. The immediate factors determining the assemblage in aircraft are: (1) the abundance of species in the immediate vicinity of airstrips and (2) the behavior of species. The first factor in turn depends upon the season. Experience along this route has shown that the incidence of insects in planes may be reduced by maintaining a so-called "sanitated" airport and by parking planes away from the edges of jungles, fields, and watercourses. Planes parked in the middle of extensive surfaced or cleared areas picked up fewer insects than those parked adjacent to vegetation. That effective sanitation of airport areas also aids in reducing the number of insects in planes was shown in a particularly striking manner at one field where the success of a malaria control program caused a reduction in the number of anophelines in planes to a point where none was found over a period of 18 months. Along the route studied it is necessary to control the cabin only. Standard procedures involving the proper use of aerosol bombs have proved effective and adequate.—7-14-45.

DDT Compared with Other Insecticides for Control of Hemipterous Insects on Cotton

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Tests on caged plants with DDT dusts conducted at Mesa, Ariz., in the fall of 1943 and spring of 1944 showed a higher mortality of the pentatomids and mirids that cause serious losses to Arizona cotton than the recommended sulfur-arsenical mixtures. The principal hemipterous insects (Cassidy & Barber 1938) that effect cotton are the pentatomids *Euschistus impictiventris* Stål., *Chlorochroa sayi* Stål., *Thyanta custator* (Fabr.), and the mirids *Lygus* spp. and *Creontiades femoralis* Van D. The relative abundance and damage caused by the species at different times varies greatly. *Adelphocoris superbus* (Uhler) and several other species are of minor importance.

Extensive experiments over a number of years (Cassidy & Barber 1939, 1940, 1941) have shown that profitable gains in seed-cotton yields are usually obtained by the proper use of sulfur-arsenical dusts, but the results have been somewhat variable. These dusts, principally paris green 7.5 per cent plus sulfur 92.5 per cent, reduced the mirid populations to an appreciable extent, but were not so effective against pentatomids under field conditions. A more effective insecticide is therefore needed for this complex group of insects.

Because of the high effectiveness of DDT in the cage tests, field experiments to determine the relative toxicity of this insecticide were conducted at Mesa, Litchfield Park, and Perryville in the Salt

[1] The author was assisted in the field by William Kauffman, Louis Sheets, and John M. Breazeale.

River Valley, and at Marana in the Santa Cruz Valley of Arizona. The material was factory-mixed 10 per cent DDT in pyrophyllite to which the diluents were added to make the desired mixtures.

HAND-DUSTING EXPERIMENTS, MESA.—A 6 by 6 latin square with .025-acre plots of short-staple cotton located on the experimental farm of the University of Arizona was used in this experiment. Seven applications of each insecticide were made with rotary hand dusters at about weekly intervals from June 30 to August 19. The various arsenical mixtures were applied at the approximate rate of 20 pounds per acre-application, and the DDT mixtures at the average rate of 30 pounds. In the first two applications 2 per cent of DDT in pyrophyllite was used and in the last five a mixture containing 4 per cent of DDT, 60 per cent of sulfur, and 36 per cent of pyrophyllite. The arsenical treatments are given in table 1. Population records were obtained nine times during the season by making 50 sweeps per plot.

As shown in table 1, each treatment was followed by significant control of injurious insects and increased yield over the checks. However, DDT with sulfur gave significantly better control and a higher yield than any of the sulfur-arsenical mixtures used. The F-test indicated that there were no significant differences between the treatment means of peak insect populations on July 13.

AIRPLANE-DUSTING EXPERIMENT, LITCHFIELD PARK.—A 31-acre field of short-staple cotton was divided into an 18½-acre plot for dusting with DDT and a 12½-acre plot as an untreated check. The treated plot was dusted six times at approximately weekly intervals, from July 11 to August 28, with DDT mixtures applied by airplane in the early morning. In the first application 2 per cent of DDT in pyrophyllite and in the last five 4 per cent of DDT with 36 per cent of pyrophyllite and 60 per cent of sulfur was used, all at the average rate of 23.7 pounds per acre-application. *Lygus* spp. were the most abundant injurious insects in this field, with *Lygus hesperus* Knight predominating. Population counts made frequently throughout the remainder of the season, by making 300 strokes with a 16-inch sweep net at three points in each plot, showed a seasonal reduction of 57.3 per cent of the injurious species in the dusted plot. This field was picked in January 1945 with a mechanical harvester, and yielded 946 pounds of seed cotton per acre in the check and 1,866 pounds in the DDT plot, or a gain of 920 pounds per acre. A 58-acre field nearby dusted three times with the 7.5 per cent paris green-sulfur mixture yielded 1348 pounds of seed cotton per acre, or 402 pounds more than the check.

AIRPLANE-DUSTING EXPERIMENT, MARANA.—A 39-acre field of short-staple cotton in the Santa Cruz Valley was divided into a 19-acre plot for dusting with

Table 1.—Comparative effectiveness of DDT and arsenicals against injurious cotton insects in latin-square experiments at Mesa, Ariz., 1944.

Treatment	Injurious Insects per 100 Strokes		Yield of Seed Cotton per Acre	Increase Over Check	
	Seasonal Average	Peak on July 13			
	Number	*Number*	*Pounds*	*Pounds*	*Per Cent*
Paris green 7½% / Sulfur 92½%	8	18	2783	368	15
Paris green 15% / Sulfur 85%	8	18	3055	640	27
Basic copper arsenate 33⅓% / Sulfur 66⅔%	9	14	2909	494	20
DDT and DDT-sulfur[1]	6	15	3433	1018	42
Calcium arsenite 10% / Sulfur 90%	10	19	2719	304	13
Check (no treatment)	13	24	2415		
Minimum significant difference, 5% level	2	—	215	—	—

[1] DDT in 2 applications, DDT-sulfur in in 5 applications.

DDT and a 20-acre plot as an untreated check. The treated plot was dusted once with 2 per cent of DDT in pyrophyllite on August 26 at the rate of 30 pounds per acre. The injurious insect populations were very low in this field throughout the season but showed a slight rise just prior to the dusting date. The seasonal average of injurious Hemiptera as determined by the sweep net was 3.6 insects per 100 strokes for the treated plot and 4.7 for the untreated plot. The treated plot yielded 2,119 pounds of seed cotton per acre and the untreated plot 2,136, or a difference of 17 pounds per acre, which was not significant. This late dusting in the presence of low insect populations did not pay.

POWER-MACHINE DUSTING EXPERIMENT, PERRYVILLE.—In this experiment 7.5 per cent paris green-sulfur mixture and dinitro-*o*-cresol (1 per cent in a Frianite, volcanic ash) were compared with DDT dusts in a seven-application schedule. In the first two applications 2 per cent of DDT in pyrophyllite was used; in the following three 4 per cent of DDT with 36 per cent of pyrophyllite and 60 per cent of sulfur; and in the last two 5 per cent of DDT in pyrophyllite. All applications were made early in the morning by a team drawn power dusting machine at approximately weekly intervals between June 28 and August 9. Each treatment and untreated check was replicated three times in 1-acre plots of short-staple cotton. The approximate rate of application was 15 pounds per acre, with the exception of the 5 per cent DDT dusts, which were applied at 30 pounds per acre

The injurious hemipterous insects migrated into this field early, and there was a continuous influx throughout the growing season. A peak population of 159 injurious insects per 100 sweeps, principally *Lygus* spp. and stinkbugs, was reached on July 10 in the check plots. In this experiment the insecticides were less effective in reducing the insect populations than in the other experiments, but the DDT mixtures were slightly more effective than the others. The gains were 551 pounds of seed cotton per acre, or 22 per cent, from the DDT and 396 pounds, or 15.8 per cent, from the paris green-sulfur, but in the plots treated with dinitro-*o*-cresol there was a loss of 22 pounds. The average yield in the check plots was 2509 pounds of seed cotton per acre.—8-25-45.

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COLONEL EMORY C. CUSHING

It has been announced that Colonel Emory C. Cushing will, upon his release from the army, become head of the Division of Insects Affecting Man and Animals in the Bureau of Entomology and Plant Quarantine.

Colonel Cushing held this position before being granted military leave and will now replace Dr. W. E. Dove, who has resigned.

Colonel Cushing was awarded the U. S. Army Typhus Commission Medal for his work in typhus control in the European Theater of Operations.

PROCEEDINGS OF THE NORTH CENTRAL STATES ENTOMOLOGISTS CONFERENCE

The proceedings of the 1945 Conference of the North Central States Entomologists have been assembled and issued in attractive mimeographed form. Much timely and interesting information is included, all of which should be of interest to entomologists, especially those who were unable to attend the conference.

Copies may be secured for the price of $1.00 per copy, so long as the supply lasts, from Professor J. J Davis, Purdue University, Lafayette, Indiana.

DDT for Bollworm Control During 1944

E. E. Ivy, C. R. Parencia, Jr., R. W. Moreland, and K. P. Ewing, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

Cage and laboratory tests at Waco, Tex., in 1943 (Ivy 1944a) showed that DDT (1-trichloro-2, 2-bis (*p*-chlorophenyl) ethane) was effective against the bollworm, *Heliothis armigera* (Hbn.), and additional tests conducted in cages and under practical field conditions in 1944 confirm these results. The product received for testing was a 10-per cent mixture with pyrophyllite. It was applied as a dust or a water-suspension spray diluted to different strengths as indicated.

Cage Tests.—Five series of tests on caged plants were conducted to compare the effectiveness of DDT dusts and sprays at different concentrations with other insecticides against insectary-reared third-instar bollworms. Accurately controlled dosages of dusts were applied to field-grown cotton plants in a dusting chamber in the same manner as in 1943 (Ivy 1944b). The sprays were applied with a modified paint gun. The materials and rates of application, numbers of larvae utilized, and net mortalities after 5 days are shown in table 1.

In the first series 4 per cent DDT at 16 pounds per acre was more effective than basic copper arsenate-sulfur applied at the same rate, or calcium arsenate, lead arsenate, or cryolite each at 8 pounds. In series 2 the 4 and 2 per cent DDT dusts at the rate of 16 pounds per acre were more effective than calcium arsenate at 8 pounds, but at the lower concentrations DDT was much less effective. In series 3 a high poundage of a low concentration was more effective than a low poundage of a higher concentration, when used at the rate of 0.32 pound of DDT per acre. In series 4 a mixture of calcium arsenate and DDT was slightly more effective than DDT-pyrophyllite alone, and considerably more effective than a mixture of calcium arsenate and pyrophyllite. In series 5 four concentrations of DDT sprays were compared with a 4 per cent dust. A water spray containing 1.28 pounds of DDT per acre gave 100 per cent mortality, and the less concentrated sprays caused correspondingly lower mortalities. Spraying or dusting with 0.64 pound of DDT per acre was about equally effective.

In three other cage tests to compare the residual effect of DDT, field-growing cotton plants were sprayed or dusted 4 times at 5-day intervals at the rate of 0.64 pound of DDT per acre-application. After the fourth application and 0.46 inch of rain, the plants were caged and bollworm larvae or eggs were placed on both treated and untreated plants. Of 30 third instars placed on the plants 1 day after the fourth application, the net mortality after 5 days was 43 per cent from the dust and 52 per cent from the spray. Of 90 first instars placed on the plants 7 days after the fourth application, the net mortality after 7 days was 93.8 per cent from the

Table 1.—Mortality of third-instar bollworms 5 days after treatment with DDT in comparison with other insecticides.

Treatment	Rate of Application per Acre		Larvae Tested	Net Mortality
	Mixture	DDT		
	Pounds	*Pounds*	*Number*	*Per Cent*
Dusts				
	Series 1			
DDT 4%[1]	16	0.64	103	84
Basic copper arsenate-sulfur (1:1)	16	—	106	73
Cryolite (88.2% sodium fluoaluminate)	8	—	102	66
Lead arsenate	8	—	89	65
Calcium arsenate	8	—	103	62
	Series 2			
DDT 4%	16	0.64	95	85
2%	16	.32	106	71
1%	16	.16	101	37
0.5%	16	.08	100	25
Calcium arsenate	8	—	103	62
	Series 3			
DDT 8%	4	0.32	104	65
4%	8	.32	107	68
2%	16	.32	108	73
1%	32	.32	106	85
Calcium arsenate	8	—	91	62
	Series 4			
Calcium arsenate plus:				
DDT 4%	16	0.64	96	89
Pyrophyllite 40%	16	—	98	68
DDT 4%	16	.64	80	86
	Series 5			
DDT 4%	16	0.64	102	92
Sprays				
	Gal.			
DDT 38.4 lb.[2]	30	1.28	92	100
19.2 lb.	30	.64	98	89
9.6 lb.	30	.32	99	66
4.8 lb.	30	.16	102	45

[1] DDT percentages refer to concentration in pyrophyllite.
[2] Quantity of 10 per cent DDT-pyrophyllite per 100 gal.

[1] In cooperation with the Texas Agricultural Experiment Station.

dust and 100 per cent from the spray. When 180 eggs were stuck to the cotton leaves 3 days after the fourth application, the mortality of the newly hatched larvae at the end of 10 days was 100 per cent from both the dust and the spray.

FIELD-PLOT EXPERIMENTS.—In a small-plot experiment at Waco, Tex. DDT-pyrophyllite dusted satisfactorily through single-nozzle hand guns, and no injury to *sypii* Glov., increased on the DDT plots about the same as on those dusted with calcium arsenate, all the plots in this experiment were dusted with nicotine on September 19 to prevent aphid damage.

Bollworm damage was well advanced when the experiment was begun, with an average of 27.1 per cent of the squares and 17.3 per cent of the bolls injured on August 1. Three square-injury records were

Table 2.—Results of field-plot experiments with DDT for control of the bollworm.

TREATMENT	RATE OF APPLICATION PER ACRE	BOLLWORM INFESTATION		BOLL WEEVIL PUNCTURED SQUARES	YIELD OF SEED COTTON PER ACRE	
		Injured Squares	Injured Bolls		Total	Gain Over Check
	Pounds	*Per Cent*	*Per Cent*	*Per Cent*	*Pounds*	*Pounds*
Small-plot experiment at Waco						
Untreated check	—	11.0	15.0	0.5	1022	—
DDT 1%	15.8	10.6	10.1	.2	1170	148
2%	15.6	7.7	7.2	.2	1176	154
4%	16.9	6.2	7.0	.7	1260	238
8%	16.3	2.9	5.2	.4	1342	320
Calcium arsenate	16.1	4.3	6.3	.1	1295	273
Difference required for significance, 5% level		3.0	3.1		181.6	
Large-plot experiment at Bryan						
Untreated check	—	22.3	12.3	1.3	1104	—
DDT 4%	16.0	9.3	3.0	.7	1840	736
Calcium arsenate	15.0	5.1	1.7	.3	1792	688
Calcium-lead arsenate[1]	12.0	7.7	2.1	1.0	1680	576

[1] Material containing 36.4% As_2O_5 and 31.6% PbO (analysis by Division of Insecticide Investigations).

the cotton plant was noticed. The plots were 10 rows wide, 0.1 acre in size, and arranged in randomized blocks with 4 replicates. The infestation and yield records were made in the usual way (Ewing and Parencia 1943) on the center portions of the 6 middle rows. Although the tests were primarily against the bollworm, observations were made on the effect of DDT on other insects.

Table 2 lists the various treatments, together with the seasonal average infestation of the bollworm and the boll weevil, *Anthonomus grandis* Boh., and yield of seed cotton for each treatment. The plots were dusted on August 2, 7, and 9, but the application on August 7 was followed by rain within 24 hours. DDT did not control the cotton leafworm, *Alabama argillacea* (Hbn.); therefore, all plots were dusted lightly with an arsenical on August 9 and September 1 for control of this insect. Since the cotton aphid, *Aphis gossypii* Glov., increased on the DDT plots about the same as on those dusted with calcium arsenate, all the plots in this experiment were dusted with nicotine on September 19 to prevent aphid damage.

Bollworm damage was well advanced when the experiment was begun, with an average of 27.1 per cent of the squares and 17.3 per cent of the bolls injured on August 1. Three square-injury records were made between August 11 and 22, and four boll-injury records between August 11 and 28. The peak boll injury was 29.3 per cent in the check on August 11.

Statistically, the square-injury records showed no significant difference between the 8 per cent DDT and the calcium arsenate, but each of these treatments was significantly better than 2 or 1 per cent DDT, or the check. The 8 per cent DDT was also significantly better than the 4 per cent DDT. Each treatment except the 1 per cent DDT was significantly better than the check.

The boll-injury records showed that each dust reduced the bollworm infestation significantly below that in the check. The 8 per cent DDT was significantly better than the 1 per cent DDT, but not significantly better than the other treatments.

Statistically, the 8 and 4 per cent DDT and calcium arsenate each produced sig-

nificantly more seed cotton than the check, but there was no significant difference in yield between insecticidal treatments.

In a large-plot field experiment at Bryan, Tex., four contiguous plots were treated as follows: Check (untreated) 1.5 acres, calcium-lead arsenate 2.5 acres, 4 per cent DDT 2.7 acres, and calcium arsenate 3.6 acres. There were no replications.

Four dust applications were made with a six-row cart duster at approximately 5-day intervals between July 26 and August 10. An arsenical for leafworm control was dusted lightly on the check plot August 9, and on the DDT plot August 16.

The DDT-pyrophyllite dusted satisfactorily through the machine and no injury to the cotton was noticed.

Neither the boll weevil nor the cotton flea hopper, *Psallus seriatus* (Reut.), was abundant enough to cause noticeable damage.

Bollworm eggs were rather abundant in these plots, averaging 84 per 100 terminals on July 24 and 33 on August 9 and 16.

The seasonal average of the five bollworm square-injury records made between July 31 and August 14 and the three boll injury records made betwen August 9 and 25 are shown in table 2.

Owing to lack of uniformity in soil and plant growth, yield records were calculated from $\frac{1}{8}$-acre areas in the plots. In pounds of seed cotton per acre the smaller gain from the calcium-lead arsenate plot was probably due to the lighter applications of this material.

SUMMARY.—In cage tests with third-instar bollworms, 4 and 2 per cent DDT were more effective but the 1 and 0.5 per cent less effective, each at 16 pounds per acre, than calcium arsenate at 8 pounds per acre. Four per cent DDT at 16 pounds was more effective than a 1:1 basic copper arsenate-sulfur mixture at 16 pounds or lead arsenate and cryolite at 8 pounds. A high poundage of a low concentration of DDT was more effective than a low poundage of a higher concentration. Immediately after application DDT was about equally effective as a dust and as a spray, but after four applications and 0.46 inch of rain the residual effect from the spray was slightly greater than from the dust.

In a field experiment with small plots arranged in randomized blocks and with three dustings at approximately 16 pound per acre-application, the gains in pounds of seed cotton per acre, were as follows: 8 per cent DDT 320 pounds, calcium arsenate 273 pounds, 4 per cent DDT 238 pounds, 2 per cent DDT 154 pounds, and 1 per cent DDT 148 pounds.

In a large-plot experiment where four dust applications were made at 5-day intervals at the rate of 16 and 15 pounds per acre-application the gain from 4 per cent DDT was 736 pounds and from calcium arsenate 688 pounds.—6-19-45.

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NEW STATE QUARANTINES

A new quarantine was promulgated by the State of Texas May 28, 1945 on account of the "Quick Decline" of citrus in California, which regulates the movement of California citrus fruit, except lemons, into the State of Texas, prohibiting such movement into the southern part of that State.

Quarantine Order No. 16, pertaining to western celery mosaic, was adopted by the State of Arizona June 28, 1945, which prohibits the entry into Arizona from any other State of the United States of all rooted celery, celeriac, carrot, dill, salad chervil, caraway, coriander, and parsley plants intended for propagation, except when certified. Certificates, issued by State officials at the point of origin, shall affirm that the quarantined articles have been grown in a district free from western celery mosaic.

On June 28, 1945 the State of Arizona also adopted an intrastate quarantine, pertaining to the peach mosaic disease, which requires special peach mosaic certificates as a condition of movement of peach mosaic hosts from the infected areas into uninfected areas of Arizona, or into other states.

DDT as a Culicine Larvicide[1]

P. M. Eide, C. C. Deonier, and R. W. Burrell,[2] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Investigations on the new synthetic organic insecticide DDT (1-trichloro-2, 2-bis (*p*-chlorophenyl) ethane), conducted at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine, have show it to have outstanding value as an anopheline larvicide (Deonier *et al.* 1945). To these mosquitoes it is much more toxic than phenothiazine and has certain advantages over paris green, the most important insecticides previously used for this purpose. This paper describes early tests[3] to determine its effectiveness against culicine larvae, both the domestic species and those breeding in ponds or salt marshes. The DDT was used in various forms—as dusts, as a surface application in oils and other solvents, and in suspensions or emulsions.

Methods.—The domestic species, *Aëdes aegypti* (L.) and *Culex quinquefasciatus* Say, were allowed to develop naturally in rain barrels. Wooden barrels of 55-gallon capacity sawed in half and filled with 21 gallons of water provided ideal breeding places. A tub filled with horse manure and water that was producing *Culex* at all times was kept nearby. The emergence from this tub kept up a large population of adults and insured ample egg laying in the test barrels. Egg laying was increased when powdered dog food was placed in the test barrels. When a heavy population of larvae had been built up in the barrels, they were treated with various formulas containing DDT or phenothiazine, and records were kept on the length of time the materials prevented breeding. The toxicity of the water was checked at intervals by dipping samples from each barrel and introducing laboratory-reared larvae. It was found that a material might be toxic to first instars but not to fourth instars. A material was considered effective until all stages of larvae were found in a barrel treated with it.

In field tests the degree of infestation of a pond or marsh to be treated was first estimated by counting the larvae in a certain number of dips taken with a 4-inch dipper. The number of dips taken depended on the size of the marsh or pond; usually 20 were sufficient. Where the breeding was extremely heavy, over 100 larvae per dip, an accurate count would be made on only a few dips, and the rest estimated. The area (or the volume, in tests on suspensions) was then determined as accurately as possible, and the treatments were applied immediately afterward.

Dust applications were made with a rotary hand duster over large areas, and with a plunger-type hand duster over the smaller ponds. Liquid applications were made with a sprayer, a sprinkling can, or simply by pouring the material on the surface of the water. In tests made on suspensions, the material was stirred in with a dipper or by wading in the pond with rubber boots. In some tests sprays were applied from airplanes by the use of special equipment developed at the Orlando laboratory.

In a number of tests with DDT in suspensions and emulsions, conducted primarily against anophelines, records were also kept on the performance of the larvicides against the culicine larvae present. Two formulas were used. One—DDT 10 per cent *Cellosolve* (ethyl ether of ethylene glycol) 80 per cent, and *Nopco 1216* (sulfonated sperm oil) 10 per cent—gave a very stable suspension, the solvent being miscible with water, so that the DDT remained in colloidal suspension. The other—DDT 20 per cent, xylene 60 per cent, and *Triton X-100* (an aralkyl polyether alcohol) 20 per cent—formed an emulsion when mixed with water.

Tests Against Domestic Culicines.—Practical tests were begun in March 1943 to determine the lasting qualities of DDT against species breeding in rain barrels. The chief species involved in these tests was *Culex quinquefasciatus*, although *C. nigripalpus* Theob. was also found during the summer months, and there were occasional specimens of *Aëdes aegypti* and *Anopheles crucians* Wied.

The results of tests comparing DDT with phenothiazine in different solvents

[1] The work described in this paper was done under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

[2] Now Captain, United States Army.

[3] Edward Nottingham assisted with the field tests.

and as dusts are shown in table 1. The dosages were heavy in this series, most of them being 0.8 to 1.6 grams per barrel. Phenothiazine was not satisfactory when applied as a dust, but when applied in alcohol so that a suspension was formed, it was effective for 2 to 3 months at 20 p.p.m. and from 21 to 25 days at 10 p.p.m.

Table 1.—Toxicity tests with DDT and phenothiazine against *Culex quinquefasciatus* in rain barrels.

Method of Application	Dosage per Barrel[1]	Effective Period	
		DDT	Phenothiazine
	Grams	*Days*	*Days*
As a dust on surface	0.015	7	—
	.4	20	—
	.8	58	0
		21	—
	1.6	166[2]	0
		133[2]	21
		363	11
		61	—
In alcohol	.8	321	25
			21
	1.6	166[2]	89
		87[2]	96
			90[2]
			63
Dust in dry barrel	1.6	180[2]	7
In acetone solution	.08	138	—
	.008	15	—
In *Cellosolve*	.8	321	—

[1] 0.08 gram per barrel is equal to approximately 1 part of DDT per million parts of water.
[2] Tubs spilled or overflowed.

DDT is toxic enough to give good results as a dust when applied at these heavy dosages, although in some of the tests no initial kill was obtained until the dust was stirred and some of it made to sink.

In one barrel breeding was not resumed for a year. Several others treated with dust on the surface gave protection for over 100 days, and may have done better still if they had not been spilled. In the barrels treated with DDT suspensions the results were equally as good and more consistent.

These results indicate that (1) DDT is more toxic than phenothiazine, (2) dusts are not so effective as suspensions, (3) where dusts are desirable, DDT is far superior to phenothiazine, and (4) both DDT and phenothiazine are effective for long periods when applied in heavy dosages. However at the low dosages DDT can be used it is probably much safer than arsenicals or paris green for treatment of artificial pools or rain barrels.

The results of tests comparing the effectiveness of DDT when applied in as uspension and in an emulsion are shown in table 2. The suspension in *Cellosolve* seems to be slightly more effective, but the difference is not great and the xylene emulsion is generally recommended because it contains a higher concentration of DDT.

Table 2.—Toxicity of DDT in suspension (DDT 10, *Nopco 1216* 10, and Cellosolve 80 per cent) and in emulsion (DDT 20, *Triton X-100* 20, and xylene 60 per cent) to *Culex quinquefasciatus* in rain barrels.

Concentration of DDT	Period of Effectiveness	
	Emulsion in Xylene	Suspension in *Cellosolve*
P.p.m.	*Days*	*Days*
0.05	5	11
.1	14	11
.5	36	32 (112)
1.0	36	32 (78)
2.0	32 (145)[1]	150
5.0	32 (246)	246

[1] *Culex* breeding, all stages, noted in these barrels. It stopped suddenly on October 14, even the pupae dying, and was not resumed for the number of days noted in the parentheses.

The effectiveness of DDT emulsions in xylene was compared when the percentage of emulsifier (*Triton X-100*) was varied from 6.6 to 20 (Table 3). The materials were measured into the barrels with a pipette, and immediately stirred with a glass rod. All the emulsions except the one containing 20 per cent of *Triton X-100* formed a slight precipitate when dropped into the water, but this disappeared with stirring. Effectiveness ranged from 31 to 68 days, but since the average number of days was greatest for the lowest and the highest percentages of emulsifier, very little difference in the emulsions is indicated.

TESTS AGAINST FRESH-WATER AND SALT-MARSH CULICINES.—Applications of DDT on ponds and marshes gave variable results against culicine mosquitoes, depending on the species involved.

Results were obtained with various suspensions against *Culex pilosus* (D. & K.), *C. nigripalpus*, *C. salinarius* Coq., and

Uranotaenia sp., which were present in anopheline-breeding ponds. A *Cellosolve* suspension of 2 p.p.m. of DDT gave a residual toxicity for 11 weeks. At 1 p.p.m. the effective period was 5 weeks, and at 0.1 p.p.m. less than 1 week. In only one test did a suspension fail to give complete mortality at 0.1 p.p.m. or over. This may have been due to the method of application, since the *Cellosolve* concentrate must be diluted in an excess of water to prevent flocculation in large particles. These preparations were mixed with water at a rate to give 10 gallons of total spray per acre. Greater or smaller dilutions of the concentrate can be used if desired.

Table 3.—Effect of concentration of emulsifier on toxicity of DDT emulsion to *Culex quinquefasciatus* in rain barrels, all at 1.0 part per million.

EMULSIFIER	DDT	XYLENE	PERIOD EFFECTIVE
Per Cent	*Per Cent*	*Per Cent*	*Days*
6.6	26.6	66.8	53
			58
			56
			Av. 56
12.5	25	62.5	31
			59
			51
			Av. 47
10	25	65	68
			31
			57
			Av. 52
20	20	60	52
			68
			57
			Av. 59

Concentrations of DDT at 1 p.p.m. or more in suspensions are shown to retain their toxicity for long periods. However, high concentrations are also toxic to aquatic animals. At 0.1 p.p.m. the toxicity to fish is greatly reduced, but the residual effect is not obtained.

A summary of results with a suspension and two emulsions of DDT under a variety of conditions where only initial kills were determined is given in table 4. The *Cellosolve* suspension gave good results at both 0.1 and 0.05 p.p.m. against all species. The xylene emulsion was 100 per cent effective against *Culex* sp. and in one test against *Aëdes taeniorhynchus* (Wied.). In two tests with this material at 0.1 and 0.05 p.p.m. a few *Aëdes* larvae were alive after 24 hours, but they were noticeably affected. For practical purposes, therefore, the xylene emulsion is as effective as the *Cellosolve* suspension at these dosages.

In one test with the xylene emulsion 0.0125 p.p.m. gave 100 per cent control, but subsequent observations showed that the concentration calculated for the whole depth was concentrated at the surface of the water. The rate of diffusion is so slow that the xylene emulsions of DDT can be used as a surface application. Through agitation of the water, however, or by using a coarse spray with considerable pressure, the emulsion can be made to diffuse throughout the water.

The results of surface applications of DDT is dust and in oil are shown in table 5. The effectiveness depended upon the species involved. Dusts containing 1 and 20 per cent of DDT in talc were not so effective against culicine larvae as against anophelines. Very poor control was given with the 20 per cent dust at 0.1 and 1 pound of DDT per acre in a salt-marsh drainage ditch teeming with *Aëdes taeniorhynchus* larvae. The 1 per cent dust at 1 pound of DDT per acre gave the best results, but even then the control was not complete.

Psorophora ciliata (F.) and *Culex salinarius* were controlled by applications of the 20 per cent DDT dusts at the rate of 1 pound of DDT per acre. It is quite likely that the dusts would have shown higher mortality against *Aëdes taeniorhynchus* if examinations had been made after longer periods, but since the larval stage is very short in these species, any larvicide that did not give good results in 24 hours would have to be considered ineffective.

Petroleum oil containing 1 to 5 per cent of DDT gave 100 per cent control of *Culex salinarius* at 0.1 pound or more of DDT per acre in ponds filled with various types of vegetation. Lower dosages were less successful. Fuel oil without DDT at 1.2 gallons per acre gave from 0 to 85 per cent reduction in larvae, depending on the type of vegetation.

DISCUSSION.—DDT shows great promise as a culicine larvicide. Its use should reduce the cost of application, make possible long residual control in static pools or other breeding places such as fire bar-

Table 4. Toxicity of DDT in a suspension and two emulsions to natural infestations of various culicine larvae.

Concentration of DDT	Pond Type	Volume of Pond	Larvae per Dip	Mortality	Species
Per Cent		*Cubic Feet*	*Number*	*Per Cent*	
DDT 10, *Cellosolve* 80, *Nopco 1216* 10 per cent (suspension)					
0.05	Roadside ditch	180	38.8	100	*Culex* sp.
	Salt-marsh drainage ditch	50	200+	100	*Aëdes taeniorhynchus* and *A. sollicitans*
.1	Weedy ditch	2080	200+	100	*Culex nigripalpus*
		1500	200+	100	*Culex nigripalpus*
	Salt-marsh drainage ditch	37.5	16	100	*Aëdes taeniorhynchus* and *A. sollicitans*
		62.5	200+	100	*Aëdes taeniorhynchus* and *A. sollicitans*
DDT 20, xylene 60, *Triton X-100* 20 per cent (emulsion)					
0.0125	*Chara*	1738	7.8	100	*Culex* sp.
.025	Grassy pot hole	45	9.8	100	*Culex sp.*
	Roadside *Chara* ditch	2033	13.3	100	*Psorophora confinnis* and *P. ciliata*
.05	Salt-marsh drainage ditch	60	200+	97.4	*Aëdes taeniorhynchus* and *A. sollicitans*
	Pontederia pool	226	10.0	100	*Culex* sp.
.1	Dense grass and *Chara*	4270	18.6	100	*Culex* sp.
	Weedy ditch	1840	100+	100	*Culex nigripalpus*
	Duck weed ditch	3000	28.2	100	*Culex nigripalpus*
	Grass and hyacinth	513	3.8	100	*Culex nigripalpus* and *Psorophora confinnis*
	Salt-marsh drainage ditch	68	50.0	100	*Aëdes taeniorhynchus* and *A. sollicitans*
		87	200+	96.5	*Aëdes taeniorhynchus* and *A. sollicitans*
DDT 5, *Triton B-1956* 2, No. 2 fuel oil 93 per cent (emulsion)					
1.0	Salt-marsh drainage ditch	200	200+	98.4	*Aëdes taeniorhynchus* and *A. sollicitans*

Table 5.—Toxicity of DDT in surface applications of dusts and oils to natural infestations of various culicine larvae.

Concentration of DDT	Rate of Application of DDT	Pond Type	Area of Pond	Larvae per Dip	Mortality	Species
Per Cent	*Pounds per Acre*		*Square Feet*	*Number*	*Per Cent*	
		Dusts in talc				
20	0.2	Roadside ditch	400	6.9	57.6	*Culex* sp. and *Psorophora confinnis*
	.1	Salt-marsh drainage ditch[1]	87	200+	37.5	*Aëdes taeniorhynchus* and *A. sollicitans*
	1.0	Salt-marsh drainage ditch[1]	75	200+	53.0	*Aëdes taeniorhynchus* and *A. sollicitans*
		Lime sink[1]	5100	6.6	100	*Aëdes taeniorhynchus* and *A. sollicitans*
		Loose *Chara*	3280	11.5	100	*Culex salinarius*
		Open cover	850	5.9	100	*Culex salinarius*
		Open cover	1300	11.2	100	*Culex salinarius*
1	.1	Salt-marsh drainage ditch	75	200+	88.6	*Aëdes taeniorhynchus* and *A. sollicitans*
	1.0	Salt-marsh drainage ditch	87	200+	98.3	*A. sollicitans*
		In fuel oil				
0.25	0.025	*Chara* and scum	3600	20.9	29.6	*Culex salinarius*
.5	.05	*Chara*, no open water	153	21.4	94.9	*Culex salinarius*
		Chara, some open water	3910	12.9	99.6	*Culex salinarius*
1.0	.1	Heavy scum and algae	160	11.8	100	*Culex salinarius*
5	.05	Grass and smartweed	360	10.8	88.9	*Culex salinarius*
	.5	Grass and smartweed	1152	9.8	100	*Culex salinarius*
		Ditch with heavy vegetation[2]	950	16.5	100	*Culex* sp.
	.1	Marsh with vegetation[3]	7.6 acres	8.3	100	*Culex* sp.
	1.0	Grass and smartweed	1092	33.5	100	*Culex salinarius*
Check (1.2 gal. of fuel oil)		Heavy *Chara*	250	8.2	42.7	*Culex salinarius*
		Chara and scum	990	2.4	85.3	*Culex salinarius*
		Grass and smartweed	700	10.8	0	*Culex salinarius*

[1] Micronized talc was used in these tests. [2] Airplane oil was used. [3] Kerosene was used.

rels, cisterns, etc., and make larvicidal treatments more efficient since the one toxic agent can be applied in so many different ways.

Many of the culicine species are more resistant to DDT than are the anophelines; a heavier dosage is therefore required to give control. As a general culicine larvicide the xylene emulsion was more effective than dusts or oil solutions. Control has been obtained with DDT in xylene emulsions in places that could not be reached with ordinary larvicidal oils. There is also the added advantage of a great reduction in material transported, since a small amount of the concentrate may be diluted with water at the breeding place.

Other emulsions have been studied, and those showing particular promise are the sulfonated dormant spray oils used in orchard sprays and certain proprietary oil products that dissolve a high percentage of DDT.

DDT has the disadvantage of being toxic to fish and other aquatic wildlife when used in suspensions at higher concentrations. Equipment in which water emulsions are used is more liable to rust than that used for applying oils.

SUMMARY.—DDT is very effective as a toxic agent for culicine mosquitoes. In suspensions 1 p.p.m. or higher concentrations show residual toxicity to species breeding in rain barrels. Suspensions and emulsions of DDT were more generally effective against the fresh-water and salt-marsh culicines than were surface applications in dusts or oil solution. As little as 0.05 p.p.m. was effective against *Aëdes taeniorhynchus* (Wied.), *A. sollicitans* (Walk.), *A. aegypti* (L.), *Psorophora confinnis* (L.-Arr.), *P. ciliata* (F.), and *Culex quinquefasciatus* Say.—6-25-45.

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DDT Dispersed from Airplanes for Control of Adult Mosquitoes[1,2]

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For a number of years airplanes have been used to disperse paris green and other materials to control mosquito larvae, but no consideration had been given to the use of this method against adult mosquitoes. This has probably been due to the fact that antilarval work has been considered the most practical malaria-control measure. Moreover, there has been a lack of cheap, effective insecticides. The war brought on situations in which our armed forces were exposed to malaria and other mosquito-borne diseases in forward areas where antilarval and other measures could not be initiated in time to prevent large numbers of men from contracting these diseases. Troops fighting for and occupying new areas are exposed to infected mosquitoes for many days before adequate control can be undertaken. Larvicides, such as oils and arsenicals, obviously could not be expected to destroy infected adults present in an area even when applications were initiated immediately after occupation of new territories.

In June 1943 tests on small plots in densely wooded areas at Cocoa, Fla., demonstrated that finely atomized sprays, aerosols, and dusts containing the new insecticide DDT (1-trichloro-2, 2-bis (*p*-chlorophenyl) ethane) were highly effective against salt-marsh mosquitoes when applied with hand equipment on the ground. This work led to studies on dispersing DDT from airplanes.

The concept of spraying areas by airplane prior to or shortly after invasion to destroy both adults and larvae was proposed by members of the Orlando, Fla.,

[1] The work described in this paper was done under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

[2] This work was done under the direction of E. F. Knipling. H. A. Jones advised on solutions used and O. M. Longcoy, an experienced pilot, flew the plane in all tests.

laboratory of the Bureau of Entomology and Plant Quarantine soon after the potentialities of DDT became apparent. Besides spraying newly occupied areas, airplanes would also be useful in treating established bases. The use of airplanes for applying DDT as a larvicide is discussed in another paper (Deonier & Burrell 1945).

This report deals with tests made with a Piper Cub airplane on the Keys near Key West, Fla., in November and December 1943, against natural populations

FIG. 1.—Dispersing DDT spray from a Cub airplane (L-4B) over open terrain.

of *Aëdes taeniorhynchus* (Wied.). The objective was to determine whether adult mosquitoes could be controlled by aerial spraying of DDT over jungle areas. These were the first tests using DDT aerial sprays, and they stimulated world-wide interest and experimentation on dispersion of DDT from aircraft The logical sequence to spraying with small airplanes was the utilization of large warplanes for this purpose. These studies are reported by Jones *et al.*[1]

DESCRIPTION OF AREA.—Dense mangrove 20 to 30 feet high covered one-third to one-half of most of the plots that were treated. The remaining area was covered with a sparse to dense growth of brush and trees. Each plot usually was bordered on one side by an open grassy area from 40 to 100 feet wide Some of the brush areas, while not having so heavy a leaf coverage as the mangrove, were so thick that it was nearly impossible for a man to crawl through them. The difficulty of penetrating a dense upper canopy of leaves, such as mangrove, with sprays from a plane is obvious. The spray particles must be small enough to penetrate the vegetation and yet not be blown away. In general, these plots contained as dense a cover as is likely to be found, and afforded a severe test of airplane spraying methods.

METHODS.—Since most of the plots were somewhat longer than wide and bordered on roads or other landmarks, the area was easily identified from the air. Spraying was done at near treetop height in regular swaths approximately 40 feet apart, at a rate of 2 to 3 quarts of liquid per acre. The equipment[2] used was installed on a Piper Cub airplane (Fig. 1).

The efficacy of the treatments was evaluated by making use of the biting habits of *Aëdes taeniorhynchus*. Experience had shown that a man stopping for a few moments in the woods would soon be covered from head to foot with hungry mosquitoes seeking to bite through his clothing and actually biting his hands and face. The ideal method would have been to count all the mosquitoes on a person after a 30 or 60 second exposure. Since this was not practicable with the manpower available, a man counted only the mosquitoes in the front of his trousers after a 30 second exposure.

Generally two men would make 10 to 20 counts each in various parts of a plot before spraying and the same number of counts at intervals after spraying. By comparing the average number of mosquitoes per man per station before and after treatment, the per cent reduction could be calculated. In all tests reported herein the mosquito counts averaged 21 to 57, in most of the plots averaging about 30. Mosquito density in the sprayed area was also compared with that in unsprayed areas nearby. These records are not included in the data, because the reduction was found to be almost identical with the before and after treatment figures. In the vicinity of Key West the daily fluctuation in the density of this species was not great in any one plot; hence one series of counts immediately before and another 24 hours after spraying gave an adequate appraisal of effectiveness of the spray.

RESULTS WITH SPRAYS.—The results of 12 spray tests on plots ranging in size from 8 to 30 acres are given in table 1. The first tests indicated that, although a reduction of the mosquito population was

[1] Jones, H. A., A. W. Lindquist, C. C. Deonier, and C. N. Husman. Early tests on the dispersion of DDT sprays from fast combat aircraft. JOUR. ECON. ENT. Submitted for publication.

[2] Designed and built by C. N. Husman and O. M. Longcoy, patent application pending.

Table 1.—Results of spraying DDT from an airplane against salt-marsh mosquitoes.

VEHICLE FOR DDT[1]	PLOT	TIME OF SPRAYING	PER CENT REDUCTION AFTER TREATMENT				
			1 Hour	4 Hours	7 Hours	24 Hours	48 Hours
		Dosage 2 quarts of spray per acre					
Emulsion	1	9 a.m.	64	64	—	95	95
	2	1 p.m.	63	82	—	97	—
	3	10 a.m.	—	61	—	80	—
	4	8 a.m.	—	—	82	99.5	92
Kerosene	5	10 a.m.	74	—	96	84	—
	6	12 noon	46	94	—	96	—
25% motor oil (S.A.E. 10) in kerosene	7	10 a.m.	—	82	88	85	—
	8	11 a.m.	—	63	82	69	—
	9	10 a.m.	—	—	95	97	—
	10	8 a.m.	—	—	92	97	—
		Dosage 3 quarts of spray per acre					
Fuel oil (No. 2)	11	9 a.m.	—	—	57	79	—
	12	10 a.m.	—	—	—	76	—

[1] 5 per cent of DDT was used in all plots except plot 12, in which the strength was 10 per cent.

evident from 1 to 7 hours after spraying, the greatest reduction was recorded at the 24-hour examination. This decrease suggests the presence of a residual deposit on the vegetation. Although 2 quarts of 5 per cent DDT solution produces an extremely small deposit when spread over an acre of vegetation apparently a sufficient amount was present to be effective.

Because of the flight habits of these mosquitoes during the night their infiltration into sprayed plots must be considered. There is no doubt that this occurred in most cases, and that the control secured against the mosquitoes present at the time of treatment was higher than the 24-hour mortality figures indicate. Some plots were rather isolated, and the infiltration of mosquitoes was not great. In such cases 48-hour counts showed satisfactory reduction.

In some tests strong winds made flying difficult and probably reduced the effectiveness of the treatment. The spraying of plots 8, 11, and 12 was made with winds of 18 to 20 miles per hour. The results were not satisfactory.

It was difficult to evaluate precisely the relative effectiveness of various sprays. The tests indicated, however, that the emulsion and the petroleum-oil mixtures were about equally effective. The 24-hour records in all the tests gave reductions ranging from 69 to 99.5 per cent. The results in plot 4 were especially good. This plot was less densely wooded than the others. In most of the tests the actual relief from biting in treated as compared with untreated areas was very pronounced. With the sprays employed the percentage reduction in mosquito annoyance was greater in 24 hours than after 6 hours.

Table 2.—Results of dispersing dusts and smokes containing DDT from an airplane against salt-marsh mosquitoes.

TREATMENT	TOTAL MATERIAL PER ACRE	TIME OF TREATMENT	PER CENT CONTROL AFTER TREATMENT			
			1 to 2 Hours	7 Hours	24 Hours	48 Hours
	Pounds					
Dusts (DDT 5%):						
Kaolin	5.4	4 p.m.	35	—	No control indicated	
Talc	5	10 p.m.	41	39	No control indicated	
		8 a.m.	—	No control indicated		
	Quarts					
Smokes (in motor oil, S.A.E. 10):						
DDT 5%	2	8 a.m.	No control indicated			
DDT 20%+cyclohexanone	2	8 a.m.	70	92	98	98

This is believed to be due to the residual action of the DDT.

RESULTS WITH DUSTS.—Three tests were made using 5 per cent of DDT in talc or kaolin over areas similar to the spray plots. The weather was ideal for dusting and the insecticide was well applied. The results given in table 2, were disappointing, since very little control was secured. This is in marked contrast to previous tests in which good control was obtained with dusts when applied with hand equipment on the ground. It is believed that the men applying the dust

FIG. 2. Dispersing DDT from a Cub airplane by injecting the DDT solution into a specially constructed exhaust pipe.

in ground operations caused the mosquitoes to fly and contact the insecticide. Airplane dusting apparently did not disturb the mosquitoes. Airplane spraying, however, possibly agitated the mosquitoes because of the oil and other solvents of DDT contained in the spray.

RESULTS WITH SMOKES.—The dispersing of insecticidal smokes from an airplane appeared to have possibilities for insect control. Preliminary tests on the ground showed that houseflies, could be killed by injecting 5 per cent of DDT in oil solutions into a specially constructed exhaust pipe of a Piper Cub airplane. It was observed, however, that both smoke and spray were produced.

This equipment was tried near Key West under jungle conditions similar to those previously described. In the first test (Table 2) an excellent smoke was produced that drifted through the trees and bushes and clung near the ground (Fig. 2). No control of mosquitoes was obtained.

In the second test, with a 20 per cent DDT solution in cyclohexanone and motor oil, excellent results were obtained, control becoming evident in less than 1 hour. A good smoke was produced, but it is believed that the greatest kill was due to the DDT spray particles present. This plot was isolated, and infiltration of mosquitoes was not severe.

SUMMARY.—Sprays containing 5 per cent of DDT dispersed from a Piper Cub airplane at the rate of 2 to 3 quarts per acre gave good reduction of adults of the salt-marsh mosquito, *Aëdes taeniorhynchus* (Wied.), in dense brush and mangrove growths. A reduction as high as 99 per cent was obtained in sprayed plots, but this excellent control was not secured in all tests because of strong winds and perhaps other factors. In tests showing a relatively low percentage of control after 24 hours, the reduction of adult mosquitoes present in the area at the time of treatment was no doubt higher than the 24-hour mortality figures would indicate. This assumption is based on the fact that in most plots there was opportunity for rapid flight of mosquitoes into the treated area from the heavily populated surrounding territory. The promising results obtained with these aerial sprays, even when applied to small plots, suggest that DDT sprays applied from aircraft might be employed to control infected disease vectors ahead of advancing troops, and in other areas where it is feasible to control adult mosquitoes by this method.

Dusts containing DDT proved ineffective in adult-mosquito control when dispersed from a plane, but this method may be useful under certain conditions.

A combination smoke and spray produced by injecting 20 per cent of DDT in cyclohexanone and motor oil into a specially constructed exhaust pipe gave excellent control of mosquitoes. Five per cent of DDT in motor oil proved ineffective.—6-25-45.

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DDT-Oil Sprays Applied from an Airplane to Control *Anopheles* and *Mansonia* Mosquitoes[1]

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The promising results obtained with DDT sprays dispersed from airplanes against adults of *Aëdes taeniorhynchus* (Wied.) in Florida (Lindquist *et al.* 1945) suggested the testing of this method against tropical anopheline mosquitoes. It was believed that, if anophelines could be destroyed by airplane spraying, the method would be of great value in reducing the incidence of malaria and other mosquito-borne diseases among troops in combat areas. Through the efforts of Lt. Col. O. R. McCoy, Office of the Surgeon General of the Army, arrangements were made to conduct the first two tests of this nature in the Panama Canal Zone during April 1944.

DESCRIPTION OF THE AREA.—The first test was conducted in a typical jungle forest on a 46-acre plot facing the Chagres River just opposite Juan Mina. This plot was 1950 feet long, approximately 1000 feet wide, and fairly level although there were several small gullies and hills. Trees about 60 feet tall formed an upper canopy underneath which grew bushes and other vegetation of varying heights, producing two or three layers that collectively were rather dense. The vegetation was still succulent even though the dry season was almost over.

The second test plot was located on the Rio Gatun, and contained vegetation similar to but somewhat more dense than that described above. The area contained about 40 acres, encompassing three peninsulas extending into Gatun Lake as well as part of the mainland. Heavy rain fell on this plot for two successive days prior to spraying.

METHODS.—A spray apparatus designed and built by C. N. Husman and O. M. Longcoy was installed in an army Cub plane by Mr. Husman. The pilot, S/Sgt. R. W. Cooper, had had no previous experience in airplane spraying or dusting, but after careful briefing did an excellent job in these texts.

The spray solution consisted of approximately 10 per cent of DDT (1-trichloro-2,2-bis(*p*-chlorophenyl) ethane) in a mixture of cyclohexanone and oil (Diesel and motor). The spray was applied in swaths 50 feet apart, and the plane was flown just above the treetops.

The method of evaluating results of the tests consisted essentially in comparing the counts of mosquitoes before and after treatment. Counts were made each night from 7 to 9 p.m. by teams of two to four men. Mosquito density was based upon the number of these insects actually biting or resting on observers. The men would sit 3 feet apart for 1 minute, and then one of the writers made counts as rapidly as possible with the aid of a flashlight. Several such records were obtained at each station each night.

Since *Mansonia* spp.,—*M. titillans* (Walk.), *M. nigricans* Coq., and *M. fasceolata* (L. -A.)—were numerous in the vicinity, records were kept on these as well as on *Anopheles* spp. The adults were easily counted because of their persistent and vicious biting habit. However, the *Anopheles* adults (predominantly *A. albimanus* Wied.) were difficult to count because of their sensitivity to light and wariness in biting, which was restricted largely to the legs and crotch.

EFFECT ON ADULTS.—*Test 1.* The first plot was sprayed at 7:30 a.m. on April 15 with 23 gallons of the DDT solution at the rate of 2 quarts (0.4 pound of DDT) per acre. There was very little breeze at the time the spray was applied. During the spraying of this plot, as well as of the second one, the mosquitoes were observed to become excited and to fly about considerably for a few minutes, probably being irritated by the odor of the cyclohexanone.

Counts of mosquitoes were made at six stations from 200 to 400 feet apart. The temperature at the time of the counts was

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine. The writers express thanks to Brig. Gen. H. C. Dooling, chief health officer, Panama Canal, and Col. Charles G. Souder, M.C., for their interest in these tests. Acknowledgment is also made of the assistance of Lt. Roy Melvin in making mosquito counts, of Capt. G. B. Fairchild, in identifying samples of mosquitoes collected, and of the advice and encouragement given by Maj. Marshall Hertig and Dr. Herbert C. Clark of the Gorgas Memorial Laboratory, Panama.

[2] Now Captain, Sanitary Corps, United States Army.

78° to 80° F. The biting of *Mansonia* was terrific, especially on the face and neck. The *Anopheles* population was low but, because of the inexperience of the counter in spotting this species and because the high biting rate of *Mansonia* impeded vision, it is believed that more were present than the records indicate.

As shown in table 1, the reduction of mosquitoes was phenomenal. A control of 98 to 100 per cent was indicated the first 2 nights after spraying, by comparison of populations before and after treatment and by comparison with an untreated area. On these nights the observers hunted assiduously for *Anopheles ablimanus*, but without success. By making additional counts after 2 and 5 minutes they obtained more records, and by remaining at the station longer they gave the mosquitoes a greater opportunity to be attracted. This procedure exceeded the requirements necessary to establish percentage control as compared with records obtained before spraying, and for this reason the figures are actually conservative. Aside from the figures, the relief from mosquito attack was amazing. The untreated check area was 300 yards across the river, and from 6 to 12 counts showed no diminution of mosquitoes present from night to night.

The records taken 4 days after spraying, on April 19, showed that infiltration had not occurred. Six days after spraying the mosquito population had increased, and a control of 70 per cent of *Mansonia* and 76 per cent of *Anopheles* was indicated as compared with the untreated area. When the final examination of the plot was made 21 days after spraying, there were as many mosquitoes in the treated areas as in the untreated area. Inasmuch as the treatment gave control for 4 days, spraying of relatively small areas out of doors may have great possibilities for control of malaria and other mosquito-borne diseases.

Table 1.—Records of mosquitoes before and after aerial spraying with DDT in jungle plot on the Chagres River, Panama. Spray applied on the morning of April 15; counts made in the evening. Figures represent average number of mosquitoes per man per minute.

Station No.	Before Spraying		After Spraying									
	April 13 (39 counts)	April 14 (36 counts)	April 15 (72 counts)		April 16 (72 counts)		April 19 (36 counts)		April 21 (12 counts)		May 6 (8 counts)	
1 *Mansonia*	20	34	0.5		0.8		0.7		6		14	
Anopheles	0.2	2		0		0		0		0		1
2 *Mansonia*	4	20	0		.25		0		0		22	
Anopheles	2	5		0		0		0		0		0.5
3 *Mansonia*	15	9	.25		.08		0.3		8		23	
Anopheles	0.2	0.2		0		0		0		0		2
4 *Mansonia*	35	15	.17		1.2		.5		12		30	
Anopheles	5	0.8		0		0		—		1		1
5 *Mansonia*	34	21	.08		.9		1.3		—		—	
Anopheles	0	2		0		0		0.17		—		—
6 *Mansonia*	45	26	.08		.17		1		—		—	
Anopheles	1	2.5		0		0		0		—		—
Average												
Mansonia	24	21	.18		.46		.64		6.5		22	
Anopheles	1	1.3		0		0		0.025		0.25		1.12
Average in untreated area												
Mansonia			13		31		40		—		26	
Anopheles				1.5		8.5		5		—		3
			Per Cent Reduction									
After treatment[1]												
Mansonia			99.2		98.		97.2		71.1		0	
Anopheles				100		100		97.8		78.3		0
Compared with untreated area (6 to 12 counts)												
Mansonia			98.5		98.5		98.4		70.4		0	
Anopheles				100		100		99.5		76.3		0

[1] Based on average of 2 nights before spraying.

Test 2. The second plot was sprayed at 7 a.m. on April 20 with the same solution, dosage, and equipment as described above. There was practically no breeze, and the foliage was wet from the rain of the previous day.

Mosquito populations were evaluated in the same way as in the first test. Six stations were established and 2 men at each of 3 stations made records simultaneously. These data are given in table 2. Stations 4, 5, and 6 in the northeast sector

harbored a much greater population than the other stations. As many as 38 anophelines were counted in 1 minute, but since all stations were averaged the final plot averages were 19 and 13 on the 2 nights before treatment. Stations 4 and 5 were visited twice every evening; the second count made an hour after the first showed fewer mosquitoes than the first count. A control of 90 to 98 per cent of anophelines was demonstrated by a comparison of adult abundance before and after spraying and by comparison with an untreated area

larvae of any species. Not only was the immediate control perfect, but the abundance of oil on the surfcae of the sheltered lagoon suggested that effectiveness might persist for a week or more. The vegetation was dense enough to serve as an effective holding and residual surface, which actually prolonged larcividal effectiveness. Breeding did not occur for over 1 week, and it was repressed for an additional week.

Observations during and after treatment showed that perfect coverage was

Table 2.—Records of mosquitoes before and after aerial spraying with DDT in a jungle plot on the Rio Gatun, Panama. Spray applied on the morning of April 20; counts made in the evening. Figures represent average number of mosquitoes per man per minute.

Station No.	Before Spraying				After Spraying			
	April 18 (14 counts)		April 19 (48 counts)		April 20 (48 counts)		April 21 (48 counts)	
	Mansonia	*Anopheles*	*Mansonia*	*Anopheles*	*Mansonia*	*Anopheles*	*Mansonia*	*Anopheles*
1	—	—	5.3	13	0.17	1.7	0.17	0.5
2	—	—	2.7	.3	.17	0	.5	.17
3	2.5	4.5	3.5	.5	0	0	0	0
4	2.5	24	3.7	19	0	0	.33	.66
5	7	28	4.8	19	.42	.33	1.8	1.2
6	—	—	4.1	14	.33	.66	0	0
Average	4.7	19	4	13	.19	.37	.58	.45
Average in untreated area					13	8.5	6	4.6
				Per Cent Reduction				
After treatment[1]					95.6	97.7	86.7	97.2
Compared with untreated area (from 5 to 10 counts)					98.5	95.6	90.3	90.2

[1] Based on average of 2 nights before spraying.

the first 2 days after spraying. *Mansonia* reductions ranged from 87 to 98 per cent.

Of interest in the work on this plot were the independent observations and study of Maj. C. H. Kearney, who, with six enlisted Army men with experience in jungle warfare spent three nights in the area, one before and two after spraying. His records showed a 98 per cent reduction of mosquitoes, which figure agrees closely with those given in table 2.

EFFECTS ON LARVAL POPULATIONS.—In the first test area was a shallow lagoon of several acres, filled with surface vegetation (*Naias*), in which *Anopheles albimanus* and *Culex* sp. were breeding in large numbers. Pre-treatment checks revealed populatoins of 5 and 11 larvae per dip, respectively. This lagoon was treated in the course of spraying the wooded section against adult mosquitoes.

An exhaustive check 24 hours after treatment failed to reveal a single living

obtained throughout the breeding area, and even beyond on the open river for a distance of 100 to 125 feet. It was therefore clear, as first shown by Deonier *et al.* (1945), that airplane spraying with DDT is a highly effective means of applying larvicides to large breeding areas which are inaccessible or cannot be adequately covered by ordinary means. Under normal conditions it is also believed that a dosage of only 1 quart per care would provide satisfactory control of breeding, at least of the anophelines.

SUMMARY.—In two tests conducted in the Panama Canal Zone during 1944, sprays containing 10 per cent of DDT in oil were dispersed over jungle forest areas from a Cub airplane equipped with a portable spray unit. These sprays proved highly effective against adult *Anopheles* and *Mansonia* mosquitoes. In one test a reduction of 98 to 100 per cent of *Anopheles albimanus* Wied. and 98 per cent of

Mansonia spp. was obtained during a 4-day period after spraying. Six days after spraying some infiltration of adults had taken place, and a reduction of 70 per cent of *Mansonia* and 76 per cent of *Anopheles* was indicated. Records 21 days after spraying showed as many mosquitoes in the treated areas as in the untreated check area. Both *Anopheles* and *Culex* larvae were controlled by the aerial spraying.

In a second test a control of anophelines of 90 to 98 per cent was demonstrated when adult abundance was compared before and after spraying and with an untreated area the first 2 days after spraying, at which time the test was terminated.

These preliminary tests fully confirmed the results of earlier tests against *Aëdes taeniorhynchus* (Wied.), and represent the first demonstration of the effectiveness and practicability of airplane spraying of jungle forests against *Anopheles* and other adult mosquitoes. As a result of these tests the systematic spraying of large areas was recognized as a potent weapon for malaria control, especially under certain military conditions, and, consequently, research was stimulated along this line with all types of aircraft.

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DDT Surface Sprays for Control of Stablefly Breeding in Shore Deposits of Marine Grass[1]

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Along the coast of the Gulf of Mexico in northwestern Florida, from Pensacola east to about the St. Mark's River, a distance of over 200 miles, the stablefly, *Stomoxys calcitrans* (L.), is a perennial pest of major importance during late summer and early fall. Locally the stablefly is known as the dog fly. Outbreaks of these flies, which are vicious biting pests of man and animals, have long been a source of severe losses to livestock and resort interests in this part of Florida, but since the war their importance has been greatly increased because of the military-training activities located in this area.

In 1940 (Simmons & Dove 1941a) the breeding medium involved in these outbreaks was determined as the deposits of marine grasses which are cast ashore in huge quantities on the beaches of the partially landlocked bays and sounds. Since these grasses grow principally in the brackish water of the bay bottoms, the open Gulf beaches are not usually involved in this fly problem. The Bureau of Entomology and Plant Quarantine at its Panama City laboratory has been conducting control operations over most of this area since 1941, using a creosote-bay water spray on the grass deposits as they are washed ashore (Simmons & Dove 1942). This method, while highly effective, involves considerable transportation as well as operational handicaps and expense.

During the fly season of 1944 an attempt was made to determine the possibility of simplifying the control by the use of light surface applications of DDT (1-trichloro-2,2-bis(*p*-chlorophenyl)ethane) emulsified in bay water. Tests with several other types of fly-breeding media have shown that DDT sprays which wet the surface to a depth of about three-fourths inch and leave a residual deposit of 300 to 400 mg. of DDT per square foot kill 90 to 95 per cent of emerging adults of both the dog fly and the housefly, *Musca domestica* L.

MATERIALS.—Two materials have been tested, technical DDT and DDT residual oil, the latter being a dark-brown sirupy liquid obtained as a byproduct in the manufacture of DDT.

Two lots of residual oil were obtained from the manufacturer. Lot 1 contained considerable amounts of crystalline solids.

[1] Acknowledgment is made to K. D. Quarterman, in charge of dog fly control, for cooperation and assistance in this work.

Lot 2, which was received late in the season, contained no solids, and it was learned later that a solvent had been added at the factory before shipment. Most of this lot was used in beach-control activities.

Stock solutions of both technical DDT and the DDT residual oil were prepared with commercial xylene as the solvent and *Triton X-100* (polyethylene glycol phenylisoactyl ether) as the emulsifier, and from these solutions the sprays were made up in desired concentration by dilution with bay water. The distillation range of the xylene as stated by the manufacturer was 135°–155° C. Stock solutions were tried containing various proportions of the basic materials. The stock solution of technical DDT contained 20 to 35 per cent of DDT, and the DDT residual oil contained 50 to 88 per cent. The xylene content was held to 60 per cent in all the stock solutions of DDT and to 30 per cent or less in those of the residual oil. From 5 to 20 per cent of emulsifier was used. Reducing the amount below 20 per cent resulted in slightly less stable emulsions, but where tank agitation is adequate this is not considered important.

In one test a 10 per cent DDT-pyrophyllite dust was applied as a suspension in bay water. A very small amount of *Triton X-100* (about 1 teaspoonful per quart) was added as a wetting agent.

PLOT TESTS.—To determine dosage requirements and methods of application in relation to the many variables present in beach spraying, plot tests were conducted under controlled conditions. Uniformly and heavily infested grass was placed in plots 4 feet square by 8 inches deep and surface-treated with definite amounts of spray. The total exposed surface area of the sides and top of each of these plots was approximately 25 square feet. The emulsions were applied with a knapsack sprayer, and a screen emergence cage was placed over each plot immediately after treatment. Results of the treatments were based on daily records of surviving flies able to leave the cages by flight when the tops were removed. Checks were obtained by caging comparable untreated material. Some of these tests were carried out in the insectary yard, where no tide washing was involved, and others on the beach, where tidal submergence was an important factor.

The results of plot tests carried on at the insectary are shown in table 1. The plots receiving graduated amounts of a bay-water emulsion containing 0.25 per cent of technical DDT gave results indicating fly mortalities of 92 to 96 per cent. Although the mortalities were somewhat out of line with the doses applied, they were in all cases above 90 per cent. The plots receiving an emulsion containing 0.5 per cent of DDT gave mortalities ranging from 92 to 97 per cent. These results were also somewhat erratic, but work with other types of media has shown that kills are dependent more on the amount of residue than upon the quantity of spray applied.

Table 1.—Insectary plot tests of bay-water emulsions of DDT and DDT residual oil applied as surface sprays to marine grass infested with dog flies.

Concentration of Insecticide	Quantity of Spray per Plot[1]	Insecticide Residue per Square Foot	Flies Surviving in		Mortality
			Treated Grass	Untreated Grass	
Per cent	*Quarts*	*Milligrams*	*Number*	*Number*	*Per cent*
		Technical DDT			
0.25	2.0	190	177	2112	92
	3.0	285	108	2112	95
	4.0	380	91	2112	96
	5.0	475	176	2112	92
.5	1.0	190	127	2112	94
	1.5	285	87	2112	96
	2.0	380	68	2112	97
	2.5	475	75	2112	96
	2.5[2]	475	69	837	92
	2.0	380	20	682	97
		DDT residual oil (liquid and solids)[3]			
2.5	2.5	2375	70	999	93
5.0	2.5	4750	7	632	99
		DDT residual oil (liquid only)			
.5	2.0	380	181	682	74
1.0	2.0	760	77	682	89
2.0	2.0	1520	42	682	94
2.5	2.0	1900	37	682	95
5.0	2.0	3800	7	682	99

[1] For convenience in calculation 1 quart was considered equivalent to 950 ml.
[2] Duplicated test.
[3] Three replicated tests.

For beach applications it is impracticable to use emulsions containing less than 0.5 per cent of DDT. Two gallons of spray per 100 square feet at this concentration give a residual deposit of about 380 mg. of DDT per square foot, which has been consistently effective in the plot tests (2 quarts per 25 square feet). The same deposit could be applied in smaller amounts of spray by increasing the concentration but it is believed inadvisable to do so because of possible faulty coverage under the present method of application.

The first lot of DDT residual oil, which

contained crystalline solids, was used in these tests. Both the entire mass of liquid and solids and the liquid portion alone were tested. The solids in the mixed portion were redistributed in the liquid by agitation before use. The liquid portion was separated by decanting.

As will be seen in table 1, there was little difference in the toxicity of the two portions. Five tests of the liquid portion, applied in graduated doses, gave fly mortalities of 74 to 99 per cent. The toxicity of DDT appears to be about five times that of DDT residual oil.

considerably from day to day, but these plots were from one-half to two-thirds submerged at high tide and at times completely inundated for short periods. The parallel replicates of these plots were caged at the insectary. Emergence records were made daily on the entire series.

The results of these tests, which are summarized in table 2, indicate a mortality of 76 per cent due to tidal submergence Although the effect of submergence upon the insecticide was evidently rather severe in the DDT-treated plot, the combined effect of the tide and the spray application

Table 2.—Plot tests showing effect of exposure to tidal washing on the mortality of dog flies in marine grass sprayed with DDT and DDT residual oil in bay-water emulsion or suspension.

Treatment	Concentration of Insecticide	Insecticide Residue per Square Foot	Flies Surviving	
			Not Tide-washed	Tide-washed
	Per Cent	*Milligrams*	*Number*	*Number*
Series 1, dosage 2 quarts per plot				
Emulsions:				
DDT	0.5	380	1	60
DDT residual oil (lot 1, liquid portion)	2.5	1900	19	13
Check (untreated)	—	—	621	152
Series 2, dosage 4 quarts per plot				
DDT-pyrophyllite suspension	0.25	380	15	45
DDT residual oil (lot 2), emulsion	1.25	1900	1	6
	1.75	2660	0	2
Check (untreated)	—	—	69	33

The control of dog fly breeding in bay grass is complicated by the fact that much of the grass is subjected to partial tidal inundation. The effect of this submergence on the performance on insecticide applications is difficult to appraise. Storm tides in themselves are often an important factor in natural control.

Tests were also made to determine the effect of tidal submergence on infestations in both treated and untreated grass. Six plots of grass heavily infested with eggs, larvae, and pupae of the dog fly were placed on screen trays. In one series two of these plots were surface-treated with 2 quarts of 0.5 per cent DDT emulsion and two with the same amount of a 2.5 per cent DDT residual-oil emulsion; two plots were untreated. On the treated plots the residue load of DDT was approximately 380 mg. per square foot and of residual oil 1900 mg. One plot of each treatment and one check were transferred to the beach and placed in the tide wash. Tides vary

resulted in a kill which was approximately 90 per cent of that obtained with the check out of water. In the plots treated with a 2.5 per cent emulsion of DDT residual oil, more flies survived from the plot not tide-washed than from its tide-washed parallel.

In a second series two emulsions of DDT residual oil (lot 2) were compared with a 10 per cent DDT-pyrophyllite dust applied as a suspension in bay water. Owing to the difficulty of keeping the suspension properly agitated because of the large amount of pyrophyllite present, the DDT content of the diluted spray was cut to 0.25 per cent and the quantity of spray increased to 4 quarts.

The dust suspension was definitely less effective than the same amount of DDT applied in a water emulsion (series 1). This was true of both the plot subjected to tidal inundation and its parallel out of water. The DDT residual oil applied at five times the concentration of technical

DDT was, with one exception, equally as effective, and at seven times the strength of DDT the residual oil was definitely more lethal, both when subjected to tidal submergence and when entirely out of water.

In the second series of tests the infestation was less dense than in the first, because the series was not set up until October 25, when fly activity was past its peak. The emergence records were continued until December 23; one fly emerged as late as November 22.

Storm tides of several days' duration frequently throw immense quantities of grass far above normal tide levels, and such grass may become a source of prolific fly breeding. Tests were therefore made to determine the period green uninfested grass is protected by a DDT surface spray, when tide washing is not a factor. Four standard plots of green uninfested grass were sprayed with 2 quarts each of a 0.5 per cent DDT-bay water emulsion. Four similar plots were left untreated as checks. Two of these eight plots, one treated and one untreated, were exposed to infestation for 15 days immediately after spraying. The other three pairs of plots were protected under large screen cages and exposed, respectively, at the end of 7, 21, and 28 days after spraying. After 14 days exposure to fly infestations, each pair was caged and fly emergence checked daily. No flies emerged from the plot treated and exposed immediately after spraying, while 151 emerged from its check. No flies emerged from the plot protected for 7 days subsequent to spraying, while 115 emerged from the check. The treated plot protected for 21 days produced 1 fly and the check 6 flies, while the treated and the check plot protected for 28 days before exposure produced 4 flies each. This test verifies a point determined in 1942, *i.e.*, that grass 3 to 4 weeks old is definitely past critical susceptibility as a fly-breeding medium (Simmons 1944).

BEACH TESTS.—A number of beach tests were made in which a half-mile to a mile of beach was treated in a manner simulating control procedure. For this work a small power sprayer with a 50-gallon tank and a pump delivery of about 3 gallons per minute at 350 pounds pressure was loaded in a flat-bottomed skiff and propelled along the shore. At intervals, where examination revealed appreciable infestation, an emergence cage was erected over sprayed material and another over comparable unsprayed material. Cage sites were established prior to spraying, with as little disturbance to the grass deposits as possible. The grass deposits were heavily tide-washed in some instances, and entirely out of water in others.

Since these tests were conducted in widely separated areas, it was rarely possible to make fly counts oftener than every other day, although sufficient daily observations were included to check the reliability of that procedure. Table 3 shows the results of these tests.

Heavy tidal washing can be expected to lessen the durability of any insecticide application. It is difficult to understand how fly larvae tolerate the tidal submergence to the extent they apparently do. They are, however, extremely sensitive to moisture changes in the media, and are inclined to migrate upward as the water table rises. Furthermore, experimentally larvae entirely submerged for 5 to 6 hours have recovered, and it is probable that pupae are even more resistant. In the test at Allenton (Table 3), although the

Table 3.—Beach tests of bay-water emulsions of DDT and DDT residual oil applied to deposits of infested marine grass for the control of the dog fly.

Treatment	Concentration	Date Applied	Location (Florida)	Tidal Washing	Emergence Cages Placed Over Grass		Observation Period	Flies Surviving		Indicated Mortality
					Treated	Untreated		Treated	Untreated	
	Per cent				*Number*	*Number*	*Days*	*Number*	*Number*	*Per cent*
DDT	0.5	Aug. 23	Allenton	Heavy	6	6	26	15	91	84
		Sept. 27	West Bay	Moderate	5	5	47	21	278	90
		Oct. 5	Big Lagoon	Slight	4	2	36	1	412	99
DDT residual oil (lot 1)	3.0	Oct. 5	Big Lagoon	None	4	2	36	0	93	100
Total								37	874	

grass was heavily tide-washed for a major part of the 26-day observation period, the check cages produced 91 flies, against 15 from cages over treated material. Eggs present on the grass at the time of spraying were apparently eliminated by the treatment, probably because of their exposed location. Factual evidence of this is contained in the detailed records of the test at West Bay, where the 21 flies surviving in the treated plots appeared in about the first 10 days after treatment. On all the plots in this test eggs were present in liberal numbers at the time of spraying, and the 278 flies from the check cages appeared in two distinct waves—one of 211 flies emerging in the first 10 to 12 days, and the other of 67 flies in the last 2 weeks of the test. This test was under observation 47 days, and the last 67 flies to emerge in the check plots were undoubtedly from eggs present on the grass at the time of the treatment.

In the addition to the beach tests, a substantial mileage of grass deposits was treated with surface applications of either DDT or DDT residual oil. These applications provided a means of studying the equipment and labor requirements of this type of control under a variety of the natural handicaps. They also permitted the treatment of several highly critical areas which for various reasons could not be sprayed with creosote. In the entire season's operations, including both experimental and control areas, 75 miles of shore line containing 41 miles of grass were treated with 7545 gallons of spray, or at an average rate of about 186 gallons per mile. The grass deposits varied from heavy to light and were representative of the conditions usually encountered. The maximum amount of spray applied per mile was 600 gallons and the minimum 100 gallons. It has been concluded that 200 gallons is sufficient for average conditions.

The DDT surface sprays have many advantages over the present creosote-bay water sprays, chief of which are large savings in material costs, transportation, labor, and equipment. Most of the bays on which control operations are required are extremely shallow, and therefore offer considerable difficulties, especially at low tide, in the use of the heavy deep-draft equipment necessary for creosote spraying. The ideal equipment for applying the DDT sprays has not yet been devised, but in general it should consist of light sprayers in mobile, shallow-draft, self-propelled boats.

SUMMARY.—Tests of light surface sprays of bay-water emulsions of both technical DDT and the DDT residual oil have shown that either of these materials can be effectively used as a control for stableflies, or dog flies, *Stomoxys calcitrans* (L.), breeding in deposits of marine grass. Small-plot tests have shown that DDT is approximately five times as toxic as DDT residual oil. When applied to grass already infested at a concentration of 0.5 per cent for DDT and 2.5 per cent for the residual oil, at the rate of 2 gallons per 100 square feet, a 90 to 95 per cent mortality of emerging adults was obtained. When DDT was applied at the same concentration and dosage to uninfested green grass not subjected to tidal washing, the grass was permanently protected from critical fly breeding. Infested grass treated and subjected to tide wash showed an indicated mortality of 90 per cent from the combined effect of the spraying and tidal submergence. Beach tests, where materials were applied in a manner simulating control procedure, gave an indicated control of 84 per cent on heavily tide-washed material and 99 to 100 per cent control on grass deposits not subjected to any tidal inundation. The maximum amount of dilute spray applied per mile was 600 gallons, and the minimum 100 gallons.—8-25-45.

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DDT to Control Ticks on Vegetation

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In a recent paper (1944) the authors discussed the toxicity of DDT (1-trichloro-2,2-bis(*p*-chlorophenyl)ethane) to unfed ticks, and reported that it had been used successfully to control the blacklegged tick, *Ixodes ricinus scapularis* Say, on roadside vegetation. It was stated that, of various solvents tested, pine oil produced the most effective sprays, when used with a satisfactory emulsifier. The following discussion is presented to recommend the use of soluble pine oil,[1] a commercial product which contains an emulsifier, and to report successful field tests against other species of ticks. Soluble pine oils are available in most localities, as they are widely marketed as pine oil disinfectants.

Sprays containing DDT (technical grade) dissolved in soluble pine oil and in plain pine oil were compared in laboratory tests against unfed adults of the lone star tick, *Amblyomma americanum* (L.), and the American dog tick, *Dermacentor variabilis* (Say). Both solvents were used at the rate of 5 fluid ounces to 1 avoirdupois ounce of DDT. An emulsifier (*Areskap*[2]) was added to the plain pine oil, but the soluble pine oil was used without an additional emulsifier. The soluble-pine-oil emulsions were slightly less effective at low concentrations of DDT, but at the strength used in field applications both were equally effective and the former were more stable. Soluble pine oil was therefore used in the following field experiments.

TESTS AGAINST THE LONE STAR TICK.—Field tests against *Amblyomma americanum* were made with dusts and sprays containing DDT and other insecticides in plots of $\frac{1}{8}$ or $\frac{1}{16}$ acre laid out in heavily infested woodland near Savannah, Ga. Collections were made by dragging a sheet of white flannel, 1 yard wide by $1\frac{1}{2}$ yards long, across each plot along eight parallel lines. At the end of each two crossings all ticks were removed from the cloth and returned to the vegetation. Shortly after the original collection was made, usually on the next day, the test plots were sprayed or dusted; one plot was left untreated as a check. Collections were made at intervals thereafter in the same manner as the original collection.

The amount of spray required to cover a plot ranged from 10 to 13 gallons, depending on the density of the vegetation. The entire surface of the ground and all vegetation up to 3 or 4 feet above ground were covered with the spray. No injury to plants was apparent in any of the tests.

Table 1.—Abundance of lone star ticks in woodland plots following treatment with a DDT spray applied on April 25, 1944, at the rate of 6 oz. DDT per acre.

Collection Date	Per Cent of Original Infestation After Spraying			
	DDT		Check (Untreated)	
	Nymphs (349)[1]	Adults (17)	Nymphs (189)	Adults (27)
April 27	3	6	82	122
29	1	0	118	233
May 1	1	6	127	141
5	5	0	142	181
10	3	0	146	119
15	6	12	205	211
22	6	35	167	215
June 1	2	12	152	296
17	4	59	278	637
July 1	2	47	134	193

[1] Figures in parenthesis are numbers of ticks collected on April 24, the day before the plots were sprayed.

All the tests here reported were conducted during a period of increasing tick abundance, as shown by the checks and other observations. Previous experience has shown that at such times it is especially difficult to obtain reductions in tick abundance that persist for more than a few days, as the numbers of newly active ticks are constantly increasing. The prolonged control obtained with DDT is therefore the more outstanding.

Table 1 gives results of tests of a DDT spray consisting of 0.96 ounces of DDT, 4.8 fluid ounces of soluble pine oil, and water to make 15 gallons.

The DDT gave excellent results against nymphs for 68 days, and against adults

[1] A commercial grade with a specific gravity of 0.950–0.960 at 15.5° C., containing not more than 10 per cent of water and not less than 80 per cent of destructively distilled pine oil, together with an emulsifier.

[2] Sodium monosulfonate of butylphenylphenol.

for a shorter period. Even after 53 days the adults were only 59 per cent as abundant as they were originally, whereas in the check area the relative abundance was 637 per cent.

In table 2 light and heavy applications of DDT as a dust are compared with a light application as a spray. The dusts contained 1 and 5 per cent of DDT in pyrophyllite, and the spray contained approximately 0.05 per cent of DDT, in the same formula that was used in the previous tests. The 5 per cent dust gave excellent control of nymphs and adults, holding the former to 3 per cent and the latter to days, while in the check they increased to 183 and 215 per cent, respectively.

Only once was DDT entirely ineffective against the lone star tick—when a dust containing 1 per cent of DDT was compared with one containing 3 per cent of rotenone (as ground derris root in pyrophyllite). The rates of application were 4 ounces of DDT and about 8 ounces of rotenone per acre. Neither material gave satisfactory results, and the experiment was terminated after the eleventh day.

From this series of tests it may be concluded that DDT applied at the rate of 1 pound per acre will control nymphs and

Table 2.—Comparative abundance of lone star ticks in woodland plots following treatment with DDT spray and dusts. Treatments applied on May 16, 1944. Dosage of DDT per acre: As spray, 5 oz.; as 1 per cent dust, 5 oz.; as 5 per cent dust, 3 lbs.

	Per Cent of Original Infestation After Treatment							
	DDT Spray		1% DDT Dust		5% DDT Dust		Check (Untreated)	
Collection Date	Nymphs (138)[1]	Adults (13)	Nymphs (294)	Adults (25)	Nymphs (345)	Adults (48)	Nymphs (388)	Adults (57)
May 17	16	0	20	24	2	0	70	112
18	19	38	14	16	3	0	59	72
20	33	31	33	40	3	2	90	89
22	10	0	—	—	3	6	81	102
27	9	15	19	44	2	2	87	116
June 1	6	8	18	28	3	4	74	140
7	4	8	17	48	1	4	132	291
17	3	23	13	8	1	8	136	302
July 1	7	8	13	24	0.3	2	65	91

[1] Figures in parenthesis are numbers of ticks collected on May 15, the day before the plots were treated.

8 per cent of their original number for 46 days, whereas abundance in the checks increased to 136 per cent and 302 per cent, respectively. The 1 per cent dust and the spray were not completely satisfactory, although they reduced tick abundance. The spray was less effective than in the previous test.

Heavier applications of DDT as a spray, with and without nicotine sulfate, are compared in table 3. One spray contained 1.9 ounces of DDT, 9.6 fluid ounces of soluble pine oil, and water to make 15 gallons; the other contained the same amounts of DDT and soluble pine oil and also 9.6 fluid ounces of a 40 per cent solution of nicotine sulfate. Both sprays gave excellent control of nymphs and adults, but the nicotine sulfate increased the speed of action considerably. With it the abundance of nymphs did not exceed 1 per cent of the original number, and that of adults did not exceed 4 per cent, for 37 adults of the lone star tick for a period well in excess of a month, and possibly for the entire season of activity.

Other materials are known to give good initial results, but the treated areas are subject to reinfestation, and tick abundance soon returns to about normal. It seems certain, therefore, that the DDT has a pronounced residual effect on ticks, as it does on many insects. This is confirmed by the fact that we were unsuccessful in attempts to reinfest artificially areas that had been sprayed with DDT.

Tests Against the American Dog Tick.—A single field test with DDT against adults of *Dermacentor variabilis* was conducted at West Tisbury, Mass. Since adults of this species are usually concentrated on roadside vegetation, only roadside strips were treated. Laboratory tests having indicated this species to be more resistant to DDT than *Amblyomma americanum*, the DDT content of

Table 3.—Comparative abundance of lone star ticks in woodland plots following treatment with DDT sprays, with and without nicotine sulfate. Sprays applied on June 1, 1944. Dosage per acre: DDT 1 lb., 40 per cent nicotine sulfate 5 pts.

Collection Date	Per Cent of Original Infestation After Spraying					
	DDT		DDT-Nicotine		Check (Untreated)	
	Nymphs (496)[1]	Adults (54)	Nymphs (922)	Adults (74)	Nymphs (287)	Adults (80)
June 2	13	19	1	0	137	140
3	5	0	0.5	1	148	150
5	2	6	.2	1	121	155
7	1	4	.2	1	178	208
17	0.4	4	.1	3	183	215
July 1	.6	2	.1	1	88	65
8	.4	2	.1	4	94	65

[1] Figures in parenthesis are numbers of ticks collected on May 31, the day before the plots were treated.

the spray was increased. A spray containing 9.6 ounces of DDT and 48 fluid ounces of soluble pine oil in water to make 15 gallons was compared with one containing the same amounts of DDT and soluble pine oil and also 9.6 fluid ounces of 40 per cent nicotine sulfate. A dust containing 5 per cent of DDT in pyrophyllite was included in the experiment. The results are presented in table 4. Control was better than 99 per cent with both sprays, and better than 90 per cent with the dust, for a period of 10 days. A much lighter application of DDT as a spray would probably be satisfactory.

Table 4.—Comparative abundance of American dog ticks in roadside plots following treatment with DDT. Treatments applied on June 9, 1944. Dosage of DDT per acre: With DDT spray, 7 lbs.; with DDT-nicotine spray, 9 lbs. (40 per cent nicotine sulfate, 9 pts.); with DDT dust, 3 lbs.

Collection Date	Per Cent of Original Infestation After Treatment			
	DDT Spray (450)[1]	DDT-Nicotine Spray (355)	DDT Dust (368)	Check (Untreated) (125)
June 10	0.9	0.8	12	106
12	.7	0	6	86
13	0	0	6	99
15	.2	0	4	82
19	0	.3	5	98

[1] Figures in parenthesis are numbers of ticks collected on June 8, the day before the plots were treated.

SUMMARY.—A commercial grade of soluble pine oil was found to be satisfactory as solvent and emulsifier for DDT in the preparation of sprays for tick control.

Sprays containing DDT (technical grade) dissolved in soluble pine oil and emulsified in water gave excellent control of nymphs and adults of the lone star tick, (*Amblyomma americanum* (L.), in woodland plots, when applied at the rate of 1 pound of DDT per acre. At the rate of 6 ounces of DDT per acre the control was less complete, but still highly satisfactory, and reductions in the abundance of nymphs and adults were apparent for 68 and 53 days, respectively. At 5 ounces of DDT per acre the control was less complete.

Dust containing DDT in pyrophyllite was effective at 3 pounds but not at 4 and 5 ounces of DDT per acre.

Sprays and dusts containing DDT gave excellent control of adults of the American dog tick, *Dermacentor variabilis* (Say), when applied at the rates of 9, 7, and 3 pounds of DDT per acre.—8-30-45.

LITERATURE CITED

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DDT and Rotenone Used in Oil to Control the California Red Scale

WALTER EBELING[1,2]

In field experiments on the control of the California red scale, *Aonidiella aurantii* (Mask.), DDT[3] was first used at this Station in November, 1943. Previously laboratory experiments by Lindgren *et al.* (1944) had shown very little increase in the toxicity of the oil to adult red scale attributable to the addition of DDT, but had shown a marked increase in the residual effect of the spray, that is, the ability of the residue to prevent the "crawlers," born of those insects not succumbing to the oil spray treatment, from settling on the tree surface or from reaching maturity if they did manage to settle. In the experiments discussed in this paper, a determination was made of the long-term effectiveness of DDT against the red scale in orange and lemon orchards.

The inclusion of treatments in which derris extractives or ground cube root was either added to the DDT or used alone in the oil, was prompted by the common observation that while these toxicants increased the percentage of scales killed by the spray, they often added nothing to the long-term effectiveness of the treatment as based on a comparison of the red scale infestation in the treated and untreated plots from six months to a year after treatment. The data shown in this paper tend to substantiate this belief.

MATERIALS USED AND METHODS OF APPLICATION.—The petroleum oils used in the investigation were of the following types: heavy medium spray oil, 35 per cent distilled at 636° F., viscosity 87 seconds Saybolt at 100° F., unsulfonated residue 92 per cent; light medium spray oil, 56 per cent distilled at 636° F., viscosity 70 seconds Saybolt at 100° F., unsulfonated residue 90 per cent, mineral seal oil, 90 per cent distilled at 636° F., viscosity 47 seconds Saybolt at 100° F., unsulfonated residue 88 per cent; and kerosene, initial boiling point 360° F., end point 498° F., unsulfonated residue 95 per cent.

The DDT was either dissolved in the oils at 80° C., or used in the form known as *Gesarol AK-20*, which contains 20 per cent DDT and 80 per cent of an extender, or used as a dust of 5 per cent DDT and 95 per cent talc.

The derris extractives contained 30 per cent rotenone. Five grams of derris extractives was dissolved in 100 ml. of *n*-butyl phthalate and this solution was added to the spray oil in the proportion of 1 part to 7 parts of oil. The cube root contained 5 per cent rotenone. One pound of cube root was added to whatever amount of oil was to be used in 100 gallons of spray. The cube root was mixed for a few minutes and allowed to stand in the oil for at least 20 minutes before being used.

Blood albumin spreader was added to the spray at the rate of 1 pound to 100 gallons of spray whenever the regular oil sprays were used, but when kerosene or AK-20 were used, calcium caseinate spreader was added at the rate of 1 pound to 100 gallons of spray.

The sprays were applied by means of a 400 gallon capacity power sprayer with 500 pounds pressure and using 8/64 inch disks in the nozzles. The applications were made in accordance with good commercial practice.

The dust was applied by means of the most modern type of citrus power duster.

OIL AND DDT DEPOSITS ON FOLIAGE.—In the experiments in which derris extractives and cube root were used in oil, the amount of oil deposited by the spray was determined by means of a steam-distillation method (Gunther and LaDue, 1944). It was shown that neither DDT nor cube root had any significant effect on the oil-depositing ability of the spray, but that derris extractives in *n*-butyl phthalate had a tendency to decrease deposit of oil despite the fact that the amount of oil in the sprays was always the same whether the *n*-butyl phthalate-derris extractives solution was added or not.

In the experiments in which DDT was added to the oil the amount of DDT

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[2] The writer wishes to acknowledge the assistance of Messrs. Rowland A. Maddox, Loren S. Harris, and Gene Wood, Laboratory Assistants at the Citrus Experiment Station.

[3] 2,2 bis (parachlorophenyl) 1,1,1,trichloroethane.

washed from the surface of 200 leaves, in two lots of 100 leaves each, was determined. The leaves were picked as soon as the water had evaporated after the spray treatment. The DDT was removed the following day and analyses made according to a method devised by Gunther (1945). [Previous experiments had shown that DDT had no important effect on the oil-depositing properties of the spray.]

It should be borne in mind that penetration of the oil into the under side of a citrus leaf is rapid because the stomata are located exclusively on the under side. Therefore, much of the DDT deposited by an oil spray cannot be recovered merely by washing the leaves and is therefore not included in the figures for the amount of DDT recovered in tables 1 and 2. The amount of DDT penetrating from the *Gesarol AK-20* spray would be very small, if we may judge from analogy with results obtained by Mr. Francis A. Gunther in a study of the penetration of DDT into citrus fruits.[1]

Although 5 per cent kerosene spray with DDT at a concentration of 4 grams to 100 ml. of oil contains about 15 per cent less DDT than a spray containing 10 pounds of *AK-20* to 100 gallons of spray, and much of the DDT disappears by penetration into the under side of the leaves in the case of the kerosene spray, the amount of DDT recovered on the surfaces of the leaves was about the same with the two types of spray. The immediate insecticidal effect of either spray is very small, yet the kerosene-DDT spray is much more effective in controlling the red scale than the *AK-20* spray. This indicates that the needle-like crystalline form in which the DDT is laid down by the kerosene spray is more efficient in inhibiting the settling and development of red scale crawlers than the type of deposit laid down by an aqueous suspension.

METHODS OF EVALUATING RESULTS.—Since the advantage of DDT when used against red scale lies primarily in its prolongation of the residual effect of the spray, obviously counts on per cent of initial kill reveal very little as to the ultimate effectiveness of the toxicant. In cooperation with Dr. C. O. Persing, a system of field evaluation based on population density was devised. This study is still proceeding, but pending an ultimate decision as to the exact procedure, the field evaluations have usually been based on a count of the number of adult red scale on definite "units" consisting of green twigs, leaves, or fruits, preferably the latter. Ten or 12 trees per subplot and 40 or more units per tree were examined. There were 2 or 3 subplots per treatment in each orchard. Counts of the number of adult scales per unit were made before the treatment and the post-treatment counts were made on the same trees at periods of from 3 to 14 months after treatment, depending on how rapidly the red scale population increased to the point at which adequate counts could be made.

Sometimes pre-treatment counts had to be made on a different unit than the counts made in the final appraisal of the effectiveness of the treatments. In these cases by dividing the post-treatment counts by the pre-treatment counts, figures were arrived at which showed the relative degree of infestation for the various treatments with corrections made for original differences in population density between the plots.

LONG-TERM EFFECT OF DDT USED WITH AND WITHOUT OIL.—Among five experiments made in lemon orchards in November, 1943, only two showed any substantial increase in effectiveness of the treatment caused by the addition of DDT to the oil at the rate of 4 grams to 100 ml. of oil. On the other hand, all the oil-DDT solutions applied during the summer months showed considerable increase in insecticidal effectiveness due to the DDT. This is to be expected in view of the fact that DDT is mainly effective in inhibiting the settling and development of the crawlers, and the production of crawlers is many times as great in the summer as in the winter.

Among six experiments made during the summer months the results of two, which were considered to be typical, are presented in tables 1 and 2. It can be seen from table 1 that light medium oil at only 1 per cent concentration, mineral seal oil at 1.75 per cent concentration, and kerosene at 5 per cent concentration, all three of which contained DDT at 4 grams to 100 ml. of oil, were as effective or more effective than 1.75 per cent heavy medium emulsive oil without DDT.

[1] Francis A. Gunther, 1945. Studies on the penetration of DDT into citrus fruits. Data on file at the Citrus Experiment Station. [Gesarol AK-20 consists of 1 part DDT and 4 parts of an inert extender.]

As seen in table 1, the *AK-20* spray, which contained no oil whatever, showed some insecticidal value as compared to the untreated check in the experiment discussed above, but the results were definitely unsatisfactory as compared to the regular oil spray either with or without DDT.

The 5 per cent DDT dust (Table 1) after treatment they still had only 39.2 per cent as much scale.

The writer believes that 5 per cent kerosene might be dangerous when used on young trees because of the likelihood of kerosene soaking into the trunk of the tree beneath the soil line and killing the bark unless the rather cumbersome measure of throwing a mound of soil around the trunks prior to spraying is used to avoid this type of damage. This is assumed from the fact that such injury was obtained from the use of 8 to 10 per cent kerosene spray when large quantities of kerosene were used in spraying citrus trees in the 1940–41 season. The writer believes that 3 per cent kerosene spray would probably not result in the girdling effect often obtained from the higher dosages of kerosene. No damage has been experienced so far from 3 per cent kerosene spray even when applied to young trees having a depression in the soil around the trunk to catch and confine to the trunk large quantities of spray, a condition most conducive to injury with the 8 to 10 per cent dosages of kerosene.

Table 1.—Effect of DDT added to regular spray oil, mineral seal oil, kerosene, and used as an aqueous suspension or in dust form, on the adult female red scale population in a lemon orchard. The plots were sprayed on July 19, 1944. The counts were made before treatment and again three months and six months after treatment.[1]

Treatment Number	Treatment	DDT Recovered mg./sq. cm.	Number of Scales per Unit			Corrected Relative Infestation[2]	
			Before Treatment Scales per Leaf	Oct. 6, 1945 Scales per Fruit	Jan. 26, 1945 Scales per Fruit	Oct. 6, 1945	Jan. 26, 1945
1	Emulsive heavy medium 1.75%	0.0	0.42	1.08	4.32	26	102
2	Emulsive light medium 1%, DDT 4 g.–100 cc.	1.4	0.43	0.86	6.40	20	150
3	Mineral seal oil 1.75% DDT 4 g.–100 cc.	1.9	0.36	0.57	4.13	16	114
4	Kerosene 3%, DDT 4 g.–100 cc.	4.1	0.45	1.93	—[3]	43	—
5	Kerosene 5%, DDT 4 g.–100 cc.	7.3	0.57	0.46	2.34	8	40
6	*AK-20*, 10 lb.–100 gal.	9.2	0.37	1.51	14.82	41	400
7	*AK-20*, 10 lb.–100 gal. spray. Two applications, applied 7/19/44 and 8/22/44	—	0.34	1.30	5.31	38	156
8	5% DDT dust 1.5 lb. per tree applied 7/13/44 and 8/29/44	—	0.51	6.35	—[3]	124	—
9	Check (untreated)	—	0.69	6.38	—[3]	100	—

[1] The figures which pertain to scale population are the average for three subplots.
[2] "Corrected relative infestation" is obtained by dividing the number of scales per fruit after treatment by the number of scales per leaf before treatment and multiplying by 10. Counts on the fruit could not be made before treatment because very few fruits were on the trees at that time.
[3] The plot had to be retreated because of the severe infestation before the second count was made.

appeared to have actually increased the red scale population as compared to the untreated plot.

The residual effect of the DDT when applied in kerosene sprays is very high, when one considers that kerosene alone in 3 or 5 per cent concentrations has practically no value in red scale control. In all experiments in which 5 per cent kerosene with DDT was used it was as effective or more effective than the regular oil spray treatment in reducing the red scale population over periods as long as 7 months. In the experiment shown in table 1, the trees sprayed with 5 per cent kerosene-DDT had only 31.2 per cent as much scale on the fruit as the trees sprayed with 1.75 per cent heavy medium emulsive oil 3 months after treatment, and 6 months

The 3 per cent kerosene-DDT spray was usually not as effective as regular oil spray. However, in an experiment in which the amount of DDT in the kerosene was doubled by means of a mutual solvent (cardanol) which does not result in a reduction in oil deposit as do the majority of mutual solvents, the 3 per cent kerosene-DDT was about as effective as 1.75 per cent heavy medium oil.

Unfortunately cardanol is injurious to the foliage and is for that reason unsatisfactory as a mutual solvent. Other mutual solvents are being experimented with, however, which may prove to be satisfactory from every standpoint.

The consideration of the possibility of two sprays per year with a treatment having no perceptible injurious effects to citrus trees, such as the 3 per cent kerosene-DDT spray, would appear to be justified. Accordingly in a Valencia orange orchard (Table 2) one of the treatments was two sprays with 3 per cent kerosene-DDT, the first spray applied July 21, 1944 and the second spray applied September 25, 1944, thus making an interval of two months between the two sprays. Over six months after the first treatment the trees in this plot had only 17 per cent as many adult scales on the fruit as they did at the time the plot was first sprayed (Table 2). They had about half as many scales as the trees sprayed with 1.75 per cent light medium oil-DDT and about a third as many as the trees sprayed with 1.75 per cent light medium oil without DDT.

It is hoped that the effectiveness of 3 per cent kerosene-DDT may be increased to make it comparable to the effectiveness of 5 per cent kerosene-DDT as it has performed during the past season. The following measures are being investigated to bring about this result: (1) increasing the oil-depositing properties of the kerosene spray, (2) increasing the DDT content of the spray and (3) reducing the penetration of kerosene into the various parts of the tree, thus causing more of the kerosene to volatilize before entering the tree, resulting in the liberation of greater quantities of DDT on the tree surface, where it comes in direct contact with the crawlers attempting to settle. The addition of small quantities of aluminum stearate to the kerosene, causing a gelatinization of the oil (Ebeling 1941), is very effective in retarding its penetration, even on porous bark.

The research with kerosene as a carrier of DDT is stimulated by the fact that kerosene does not have the effect of accentuating "water spot" a serious malady of navel oranges occurring during periods of prolonged rainfall. The spray oils being used at present in citrus pest control greatly accentuate the damage from "water spot."

LONG-TERM EFFECT OF THE ADDITION OF DERRIS EXTRACTIVES AND CUBE ROOT.—It has been established beyond doubt by a number of investigators that derris extractives and cube root, when added to spray oil, increase the insecticidal efficiency of the oil against red scale.

Table 2.—Effect of DDT added to regular light medium spray oil, mineral seal oil, and kerosene, on the adult female red scale population in a Valencia orange grove, as based on counts made before treatment and 6 months after treatment.[1]

TREATMENT NUMBER	TREATMENT	DDT RECOVERED mg./sq. cm.	NUMBER OF SCALES PER FRUIT		PER CENT OF PRE-TREATMENT POPULATION
			Before Treatment	Jan. 31, 1945	
1	Light medium oil 1.75%	0.0	1.10	0.54	49
2	Light medium oil 1.75% DDT 4 g.–100 cc.	2.9	3.82	1.43	37
3	Mineral seal oil 1.75% DDT 4 g.–100 cc.	1.9	3.02	1.15	38
4	Kerosene 3%, DDT 4 g.–100 cc.	4.6	1.77	1.43	81
5	Kerosene 5%, DDT 4 g.–100 cc.	7.7	2.83	0.92	32
6	Kerosene 3%, DDT 4 g.–100 cc. Two applications. Applied 7/21/44 and 9/25/44	4.8[2]	2.75	0.48	17

[1] The figures shown in this table which pertain to the scale population are the average for two subplots.
[2] This figure pertains only to the first of the two treatments which were made in this plot.

It has not been clear, however, whether the long-term effectiveness of the oil spray is increased.

Entomologists of the California Fruit Growers Exchange (Woglum 1942) made the treatment. Yet it was known that usually the initial kill of red scale was increased when the oil-toxicant sprays studied in the survey were applied. Osburn & Mathis (1944) found no significant dif-

Table 3.—The effect of derris extractives and cube root added to light medium spray oil on the adult female red scale population on lemon trees as based on counts made before treatment and at various intervals of time after treatment.

Treatment Number	Material	Oil Deposit (ml./cm.²)10⁶	Number of Scales per Fruit		Per Cent of Pre-Treatment Population
			Before Treatment	After Treatment	
	Experiment 1. Sprayed Sept. 30, 1943, counted Jan. 5, 1945.				
1	Emulsive heavy medium 2%	141	49.2	0.9	1.8
2	Emulsive heavy medium 2%, 1 qt. of 5% derris extractives in *n*-butyl phthalate to 100 gal. spray	124	62.5	0.6	1.0
3	Emulsive heavy medium 2%, 1 lb. cube root to 100 gal. spray	143	64.0	1.0	1.6
4	Emulsive heavy medium 2%, 1 lb. proprietary ground cube root powder to 100 gal. spray	165	50.6	1.6	3.2
	Experiment 2. Sprayed Nov. 16, 1943, counted Jan. 24, 1945.				
1	Emulsive light medium, 1.75%	108	1.4	0.7	51
2	Emulsive light medium 1.75%, 1 qt. of 5% derris extractives in *n*-butyl phthalate to 100 gal. spray	92	3.4	0.8	25
3	Emulsive light medium 1.75%, 1 lb. cube root to 100 gal. spray	103	0.8	0.3	41
	Experiment 3. Sprayed Nov. 16, 1943, counted Dec. 1, 1944.				
1	Emulsive heavy medium, 1.8%	182	2.8	1.2	44
2	Emulsive heavy medium, 1.8%, cube root 1 lb. to 100 gal. spray	147	3.1	1.7	53
	Experiment 4. Sprayed Nov. 18, 1943, counted Oct. 9, 1944.				
1	Emulsive light medium, 1.8%	83	74	7.0	9.5
2	Emulsive light medium 1.8%, 1 qt. 5% derris extractives in *n*-butyl phthalate to 100 gal. spray	71	64	9.8	15.2
3	Emulsive light medium 1.8%, 1 lb. cube root to 100 gal. spray	82	57	8.9	15.7
4	Emulsive light medium 1.8%, 1 lb. proprietary ground cube root powder to 100 gal. spray	83	71	9.8	13.8
	Experiment 5. Sprayed Nov. 18, 1943, counted Dec. 2, 1944.				
1	Emulsive heavy medium 1.8%	136	11.8	39.8	337
2	Emulsive heavy medium 1.8%, 1 qt. derris extractives in *n*-butyl phthalate to 100 gal. spray	131	17.7	29.6	167
3	Emulsive heavy medium 1.8%, 1 lb. cube root to 100 gal. spray	130	12.1	28.7	237

a survey of the results of the commercial spraying done with oil-rotenone sprays used during the 1941–42 spray season and could find no improvement in control attributable to the addition of rotenone to the oil when evaluations were based on population density after a generation or more of red scale had developed following

ferences in the population density of Florida red scale, *Chrysomphalus aonidium* (L.), on orange and grapefruit trees three months after treatment in plots treated with oil alone as compared to those treated with oil-derris extractives solutions, even though significantly higher kills were obtained in the latter as based

on counts made two weeks after treatment. In the experiments reported by Osburn and Mathis the concentration of derris extractives was 41 grams to a gallon of oil, or approximately 1.2 per cent.

Ebeling *et al.* (1944) showed that the differences in red scale population in oil-toxicant sprayed plots, as compared to straight oil sprayed plots, which are caused by the greater kill obtained in the former, are gradually reduced in magnitude until at the end of a 12-month period the plots may again be approximately uniform in population density. In an experiment graphically presented in the above paper, however, an oil-toxicant spray was found to have reduced the red scale population as compared to straight oil spray, even 9 months after treatment. A similar long-term benefit was obtained in an experiment made in a lemon orchard in which a light medium oil at 1.75 per cent concentration, to which 1 quart of 5 per cent derris extractives (30 per cent rotenone) in n-butyl phthalate was added to the oil, was compared with 1.75 per cent heavy medium oil. Although the oil deposit was less in the plots in which the light medium oil-toxicant was used, due to the lower viscosity of the oil and the emulsifying effect of the mutual solvent, nevertheless, the population density of the red scale was approximately the same with the 2 treatments after they had been continued for 3 years. The amount of fruit picked from the plots sprayed with the light medium oil was, in some of the heavy picks, as much as 25 per cent greater than in the plots sprayed with heavy medium oil, and the fruit was of better quality and appearance.

In the experiments presented in this paper the oil-derris extractives or oil-cube root sprays varied in their performance to such an extent that whereas they greatly increased the effectiveness of the spray in some experiments, as shown in table 3, Experiments 2 and 5, they also apparently detracted from the effectiveness of the spray in others, as definitely indicated in table 3, Experiment 4.

When cube root was added to kerosene-DDT spray at the rate of 1 lb. to 100 gallons of spray, the effectiveness of the spray, based on population density determinations at long periods after treatment, was reduced in nearly all cases; this despite the fact that cube root is especially effective in increasing the insecticidal efficiency of kerosene, when based on per cent of insects killed by the spray (Ebeling *et al.* 1944).

The effect of predators and parasites in red scale control is known to be of very minor importance and consequently the effect of the rotenone on the predators and parasites in retarding the rate of population increase can hardly be conceived as accounting for the generally ineffectual performance of the oil-rotenone sprays as used in the experiments presented in this paper. Besides, the derris extractives and cube root contributed nothing to the effectiveness of the oil-DDT sprays and in these sprays it is known that the DDT itself has a high insecticidal effect against the entomophagous insects, thus eliminating the possibility of effect of the rotenone on the predators and parasites as being a decisive factor.

As far as the writer is aware, no one has as yet offered a satisfactory explanation for the average lack of long-term effectiveness of the oil-rotenone sprays although the gradual diminution of the initial difference in population density in oil and oil-toxicant plots may be explained by the observation by Cressman & Broadbent (1944) that the rate of increase of a sparse population of red scale is greater than that of a more dense population.

The present investigations on derris extractives and cube root have shown merely that the addition of these toxicants to oil in concentrations known to increase the insecticidal effectiveness of the oil against the red scale does not necessarily increase its long-term effectiveness in controlling the scale. These results do not preclude the possibility that the same toxicants might increase the long-term effectiveness of an oil spray if used in higher concentrations in the oil. Cressman & Broadbent (1944), working with concentrations of derris extractives of 1.1 and 1.2 per cent in light medium and heavy medium spray oil, found substantial improvement in California red scale control from the oil-toxicant solutions as compared to the oil alone. The improved results were obtained in each of 5 lemon orchards. The population studies were made from 4 to 12 months after treatment. It is of interest to note, however, that Osborn & Mathis (1944) found no significant improvement in Florida red

scale control 3 months after treatment when using the same concentration of derris extractives.

EFFECT OF DDT ON SECONDARY PESTS.—In the experiments described in this paper an increase in citrus red mites, *Paratetranychus citri* (McG) and citrus aphids, *Aphis spiraecola* Patch, was noticed in the regions where these pests are normally a problem. If successful DDT spray leaving no oily residue were designed for red scale control, supplementary measures would be necessary for other pests whose population is actually increased by the DDT because of its ineffectiveness against these pests coupled with its insecticidal effectiveness against their predators or parasites.

THE EFFECT OF DDT ON CITRUS TREES.—On March 27, 1944 an experiment was begun in which blocks of 8 navel orange trees and 8 lemon trees each were sprayed with the following: (1) light medium oil-DDT 1.75 per cent (tank-mix), (2) light medium oil-DDT 1.75 per cent (tank-mix), (3) kerosene 3 per cent, (4) kerosene-DDT 3 per cent, and (5) *AK-20*, 10 pounds to 100 gallons of spray. The concentration of DDT in the oil and kerosene was 4 per cent (4 grams to 100 ml. of oil) and in the *AK-20* spray it amounted to 2 pounds of actual DDT to 100 gallons of spray. Blood albumin spreader was used in the tank mix oil spray and casein spreader was used in the kerosene and *AK-20* sprays. At the beginning of the experiment the navel orange trees were 14 years old and the lemon trees were 5 years old.

At intervals of 1 to 2 months the entire series of sprays was again applied to new blocks of trees but 4 trees in each of the original blocks of 8 trees were resprayed. Thus, with both the oranges and the lemons, 4 trees were sprayed 7 times with each of the above treatments during the period from March 27 to December 16, 1944.

The 4 orange trees sprayed with oil-DDT 7 times during the less than 9 months' period were severely damaged by the treatments and contained much dead wood. However, they appeared to be in no worse shape than the 4 orange trees sprayed with oil alone the same number of times. In the extent of damage or appearance of the foliage or fruit, no difference could be seen between the two plots, when they were examined on February 7, 1945. The blocks of lemon trees sprayed 7 times with oil or oil-DDT stood the ordeal remarkably well. A slight thinning and slightly less green color of the foliage was noticed in both plots when they were compared with adjoining trees which had received only one treatment, but again no difference of any kind was discerned between the oil sprayed and oil-DDT sprayed trees.

The 3 per cent kerosene and 3 per cent kerosene-DDT sprays caused no perceptible damage of any kind to either the orange or the lemon trees in the plots sprayed 7 times. The trees appeared as well as unsprayed trees. The bark was examined below the soil line, but no sign of injury could be found. Likewise the trees sprayed 7 times with *AK-20* ten pounds to 100 gallons, were also unharmed by the spray. Naturally then, in all plots in which the trees were sprayed only once during the year no evidence of injury from the DDT was discerned. This is in accord with our rather extensive field experience in 7 citrus-producing counties. In none of our experiments has injury attributable to DDT been found. Nevertheless, we consider that the possibility of tree damage from DDT, especially as determined by observation over a wide area and over a long period of time should be carefully considered as one of the important phases of investigation on the DDT problem.

SUMMARY.—A method was devised for evaluating the effectiveness of insecticide treatments based on population studies of the red scale at long periods after treatment. This consisted of counting the number of adult red scales on 40 twigs, leaves, or fruits per tree in subplots of 10 or 12 trees each. Two or 3 subplots were sprayed with each material. At periods of 3 to 14 months after treatment, the same trees on which the pre-treatment counts were made were again examined in order that corrections in the final ratio of population density could be made on the basis of pre-treatment variation in the plots.

In experiments in which derris extractives or cube root were added to the oil, the amount of oil deposited by the sprays was determined, and in the experiments in which only oil and DDT were used, the amount of DDT recovered from the surface was determined. A 5 per cent kero-

sene-DDT spray (4 g. of DDT to 100 ml. of kerosene) left about the same amount of DDT on the leaf surfaces as *Gesarol AK-20* used at 10 pounds to 100 gallons of spray (2 lbs. of DDT to 100 gals.), yet the former was far more effective in controlling the red scale. Apparently the needle-like crystalline form in which the DDT is deposited by a kerosene spray has greater residual insecticidal value than the form in which it is deposited by the aqueous suspensions used in the experiments.

In either the oil or the kerosene sprays, 4 grams of DDT was added to 100 ml. of oil. In 2 out of 5 treatments applied in November, 1943 the oil-DDT solution resulted in greatly improved red scale control was compared to oil alone when examinations of the plots were made approximately a year later. During the summer months the DDT increased the effectiveness of regular oil spray in all cases.

The 5 per cent kerosene-DDT spray was as good as, or better than, the usual 1.67 or 1.75 per cent regular light medium or heavy medium spray oil treatment. Three per cent kerosene-DDT spray was usually not as effective as the regular oil spray but in one experiment in which the amount of DDT was increased to 8 grams per 100 ml. of kerosene by means of a mutual solvent, the 3 per cent kerosene spray approached 1.75 per cent heavy medium oil spray in effectiveness. In an experiment in which 3 per cent kerosene-DDT was applied twice, with a 2-month interval between the sprays, this treatment was more effective in controlling the red scale than 5 per cent kerosene-DDT or 1.75 per cent light medium oil with or without DDT.

Gesarol AK-20 at the rate of 10 lbs. per 100, even when applied twice, was much inferior to regular oil spray, but showed a certain degree of effectiveness in reducing the red scale population when compared to the untreated check. A 5 per cent DDT dust applied twice at 1.5 pounds per application resulted in an increase in red scale population as compared to the untreated check.

Derris extractives or cube root added to regular oil sprays sometimes added to the effectiveness of the treatments, sometimes appeared to be of no appreciable advantage, and in one experiment they definitely reduced the effectiveness of the treatment, as compared to oil alone. When added to kerosene-DDT sprays, cube root in nearly all cases reduced the effectiveness of the treatments as compared to kerosene-DDT alone. It is known that derris extractives or cube root increase the per cent of red scale killed by the treatment, but for some unknown reason the initial advantage from the use of these toxicants is often nullified even in as short a period as 3 months.

In areas where citrus red mites and citrus aphids are ordinarily a problem, the DDT caused an increase in the number of these pests. This increase was especially noticeable when no oil of the light medium grade or heavier was used in the spray, as in the kerosene-DDT, *AK-20* or 5 per cent DDT dust treatments.

No sign of injury to orange or lemon trees attributable to DDT was noticed whether the DDT was dissolved in oil or used in any other manner.—7-3-45.

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DDT and Other Insecticides to Control the Saratoga Spittle Insect on Jack Pine

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During the summer of 1944 a study was undertaken for the purpose of learning more about the Saratoga spittle insect, *Aphrophora saratogensis* (Fitch), which since 1940 has severely injured many young pine stands in the Lake States. One phase of this study led to a preliminary investigation of the use of insecticides for controlling the insect, the results of which are presented in this paper.

Only in the adult stage does *Aphrophora saratogensis* attack pine trees. Red pine, *Pinus resinosa* Ait., and jack pine, *P. banksiana* Lamb., are the principal hosts of the imago in the Lake States. The nymphs feed on many species of herbaceous and low-growing woody plants, establishing themselves at the root collars of such plants, usually below the surface of the litter. This protected location makes it difficult to reach the nymphs with insecticides; therefore, these tests were directed against the pine-feeding adults. It was impossible, however, to apply the poison directly on the insects, because they leaped away at the least disturbance. This made it necessary to spray or dust the trees with the expectation that the insects would later come in contact with the poisons.

FIELD TESTS.—Thirty-six trees were sprayed with technical DDT (1-trichloro-2,2-bis(*p*-chlorophenyl)ethane), and four trees were treated with each of the other insecticides indicated in table 1. The sabadilla-lime mixture and the lime were used as dusts and the other materials as sprays. The DDT was dissolved in xylene, and the solution was then emulsified in water with sodium lauryl sulfate (*Dreft*), 20 grams of the emulsifier being used per 500 ml. of solution. Because there was not enough xylene on hand for the amount of spraying contemplated, about one-third of the DDT in the spray was in suspension and two-thirds was in the emulsion. This was accomplished by placing more DDT in the xylene than it would dissolve (12 ounces DDT in 1 pint of xylene). That remaining undissolved lost its lumpiness, and when it was worked into the water a good suspension was formed. For most of the tests the DDT was used at the rate of 8.3 pounds per 100 gallons of spray, which is a 1 per cent solution. Dry powdered bordeaux and lime-sulfur were used in the sprays.

All the trees treated were jack pine (height 5 to 10 ft.) and were scattered among the unsprayed trees. A small (2-gallon) compressed-air sprayer with an angle disk nozzle was used for applying the liquids, and a calcium cyanide duster

Table 1.—Reduction in abundance of spittle insects on trees treated with various insecticides.

INSECTICIDE	OBSERVATIONS	REDUCTION IN INSECTS OBSERVED AFTER							
		1 Week	2 Weeks	3 Weeks	4 Weeks	5 Weeks	6 Weeks	7 Weeks	8 Weeks
	Number	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
DDT 1%	43	—	95	96	97	84	91	86	89
Sabadilla 20% / Hydrated lime 80%	8	81	51	—	—	—	—	—	—
Hydrated lime	15	79	64	47	63	—	—	—	—
Bordeaux 4.8%	15	90	87	81	77	—	—	—	—
Bordeaux 2.4%	23	89	48	38	7	16	26	—	—
Lime-sulfur 2.4%	23	57	8	3	16	18	0	—	—

[1] This report contains the results of a cooperative study by the following agencies: The Bureau of Entomology and Plant Quarantine, the Bureau of Plant Industry, Soils, and Agricultural Engineering, and the Forest Service, all in the U. S. Department of Agriculture; the Department of Economic Entomology and the Department of Plant Pathology, of the University of Wisconsin; and the Wisconsin Conservation Commission. The writer is especially indebted to F. C. Craighead, L. W. Orr, H. J. MacAloney, H. C. Secrest, and C. L. Fluke for their suggestions in carrying out this study.

was used for the dusts. About 1 quart of solution or 8 ounces of dust was used per tree.

The values presented in table 1 are based on the insects counted on the sprayed trees during an interval of 5 minutes, as compared with similar counts made at the same time on unsprayed trees nearby. These counts were made every day or two, but are summarized by weeks. The counts on unsprayed trees ranged from 7 to 115, averaging 38.7. The smaller counts were obtained toward the end of August, at which time the insect population was decreasing.

In order to determine whether the insects were repelled by DDT before they had received a lethal dose, a cloth tray 4 feet square was used to catch the dead insects which fell from a tree sprayed with DDT. Other trays were placed beneath unsprayed trees 10, 20, and 30 feet away from the treated tree. Every day or two the dead insects on these sprays were counted and removed. The total number of dead spittle insects collected from these trays was 180 from the tray beneath the DDT-sprayed tree, 103 from the tray 10 feet away, 2 from the tray 20 feet away, and 10 from the tray 30 feet away. These data indicatd that many of the insects stayed on the sprayed tree long enough to receive a lethal dose of DDT.

CAGE TESTS.—The data in table 1 do not indicate whether the treatments were toxic or merely repellent. To obtain more information on this aspect, tests were conducted with caged material. In each test a branch from a treated pine tree was placed in a small cage with a number of field-collected insects, and the insect mortality was determined after 24 and 48 hours. The DDT-treated branches had been exposed to weathering for about 7 weeks, whereas the other insecticides were freshly applied immediately before each test. The results of these tests are presented in table 2.

The freshly applied sabadilla mixture was very toxic and the hydrated lime alone was surprisingly effective. The low toxicity of the bordeaux suggests that repellency might be the explanation for the results obtained with this insecticide as presented in table 1.

After the treated branches had been continuously exposed to weathering, only DDT retained a high degree of effectiveness (Table 3).

Table 2.—Toxicity of several insecticides to adult spittle insects placed in cages with treated pine branches.

Insecticide	Replications	Total Insects Used	Mortality After 24 Hours	Mortality After 48 Hours
	Number	*Number*	*Per cent*	*Per cent*
DDT 1 per cent	3	140	96	100
Sabadilla 20 per cent / Hydrated lime 80 per cent	2	63	97	100
Hydrated lime	3	114	62	91
Bordeaux 4.8 per cent	2	72	14	32
Lime-sulfur 2.4 per cent	1	46	9	22
Check (untreated)	3	124	4	6

Table 3.—Toxicity of several insecticides to spittle insects after the treated branches had been exposed to weathering.

Insecticide	Replications	Total Insects Used	Period of Weathering	Mortality After 24 Hours	Mortality After 48 Hours
	Number	*Number*	*Days*	*Per cent*	*Per cent*
DDT 1 per cent	3	140	48	96	100
Sabadilla 20 per cent / Hydrated lime 80 per cent	1	45	8	44	51
Hydrated lime	1	49	30	18	26
Bordeaux 4.8 per cent	1	50	20	26	46
Check (untreated)	1	49	—	2	8

When insects were caged with one treated branch and one untreated branch, the mortalities after 24 hours were as follows: DDT 38, sabadilla mixture 38, and hydrated lime 10 per cent. Two replicates were run for each insecticide, 20 to 50 insects being used for each replication. The sabadilla mixture and the lime were freshly applied, whereas the DDT-treated branches had been exposed to weathering for about 7 weeks. It would be expected that if DDT and sabadilla were not repellent, about half of the insects would have settled on the plants treated with either of these materials and been killed within 24 hours. Likewise, about 30 per cent mortality would be expected in the tests with hydrated lime.

Insects enclosed in a treated cage for various periods were also observed. At the end of the exposure period the insects were removed from the cage and placed in an untreated cage, together with an unsprayed branch. The treated cage had been sprayed with a 1 per cent solution of DDT 30 days previously, and in the

meantime exposed to the weather. The data obtained are presented in table 4.

Table 4.—Relation between period of contact with a DDT-sprayed surface and the mortality of spittle insects (1 observation).

Period of Contact	Insects Used	Mortality After	
		24 Hours	48 Hours
Minutes	*Number*	*Per Cent*	*Per Cent*
5	46	22	41
15	45	36	49
30	46	72	78
60	47	64	83
120	40	100	—

Contact with a DDT-sprayed surface for about 2 hours was necessary for all the insects to be dead at the end of 24 hours. After about half an hour the insects developed a body tremble that was apparent even when they were resting. After about 2 hours they began to lose control of balance and locomotion, and would fall over on their sides and backs, kicking violently.

Additional data on the effectiveness of DDT in preventing spittle insect attack and subsequent injury are presented in table 5. The amount of injury was determined in June 1945 by examining trees on which counts of feeding insects and feeding punctures had been made in 1944.

Comparable data could not be obtained for the other insecticides, because these materials were applied later in the season after the insects had been feeding for some time; nevertheless, when the trees were examined in June 1945, three of the four trees treated with lime and six of the eight trees treated with bordeaux were in better condition than the surrounding unsprayed trees.

Table 5.—Protection of jack pine from spittle insect attack by spraying with DDT.

Treatment	Insects Observed per 5-Minute Period[1]	Feeding Punctures per Square Centimeter[2]	Branches and Twigs Killed per Tree[3]
	Number	*Number*	*Feet*
Sprayed	3.0	0.3	0.3
Unsprayed	38.3	8.2	52.5

[1] 43 observations.
[2] 10 trees sampled.
[3] 36 trees measured.

SUMMARY.—In preliminary tests with various insecticides for control of the Saratoga spittle insect (*Aphrophora saratogensis* (Fitch)), DDT at the rate of 8.3 pounds per 100 gallons of solution was the most promising because it continued to be effective for several weeks after the trees were sprayed. A mixture of sabadilla and hydrated lime (20:80) used as a dust was very toxic when freshly applied but did not retain its toxicity when exposed on the trees. Ordinary hydrated lime and bordeaux were surprisingly effective.—8-27-45.

FEDERAL QUARANTINE ACTION

Quarantine No. 45, Gypsy and Brown-Tail Moth Quarantine.—A public hearing was held before the Bureau of Entomology and Plant Quarantine in Newark, N. J., on July 10, 1945 to consider the advisability of extending the Gypsy Moth and Brown-Tail Moth Quarantine to include the State of New York and to consider the quarantine status of an isolated infestation in the State of Pennsylvania.

The gypsy moth has been found to be present in several counties of eastern New York adjacent to the infested area in the New England States. The spread of the gypsy moth from the small isolated infestation in northeastern Pennsylvania, which has been present there for a number of years, has been prevented by a State quarantine enforced in conjunction with eradication efforts cooperatively conducted by the Federal government and the State of Pennsylvania.

Quarantine No. 52, Pink Bollworm Quarantine.—Regulation 2 of the Pink Bollworm Quarantine was revised effective May 23, 1945 to add to the lightly infested regulated area the Texas Counties of Bailey, Borden, Cochran, Coleman, Goliad, McCulloch, Nolan, Runnels, San Saba, Scurry, Taylor Victoria, and those parts of Coke and Jackson Counties not heretofore under regulation, because of the discovery of additional infestations of the pink bollworm. Although no pink bollworms were found in Borden County, it was necessary to include it because there are no gins in the county and practically all ginning is done at plants located in the infested area.

Laboratory Studies with Rotenone Oil in Sprays to Control the California Red Scale[1]

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The effectiveness of derris extractives and ground cube root in spray oil used against the California red scale, *Aonidiella aurantii* (Mask.), has been shown, and the literature has been discussed (Ebeling *et al.*, 1940, 1944). Since much of the work with extractives of rotenone-bearing plants in oil sprays has been carried on in the field, it seemed advisable to develop a laboratory method for accurately and rapidly measuring small differences in the effectiveness of various spray treatments. This method, which was developed in 1942, involves (1) the spraying of scale insects of a uniform age with a laboratory precision sprayer, (2) a standardized system of checking the mortality of the insects, and (3) determinations of oil deposit on fruit surface in the different treatments. The method is described and the results obtained with spray oil and rotenone under various conditions are reported in the present paper.

MATERIALS AND METHODS.—Derris extractives containing 30 per cent rotenone and ground cube root containing 4.3 per cent rotenone were used in these studies with three grades of oil:

Light-medium spray oil: viscosity, 70 seconds Saybolt at 100° F.; unsulfonated residue, 92 per cent; distillation, 55 per cent at 636° F.; used both as an emulsive oil,[3] with glyceryl dioleate as the emulsifier, and as a straight (tank-mix) oil,[4] with blood-albumin spreader.

Mineral seal oil: viscosity, 47 seconds Saybolt at 100° F.; unsulfonated residue, 98 per cent; distillation, 90 per cent at 595° F.

Kerosene: initial boiling point, 360° F.; end point, 498° F.; unsulfonated residue, 95 per cent plus.

The mutual solvents used included *n*-butyl phthalate, 2-(4-tertiary-butylphenoxy) ethanol, di-isobutyl ketone, di-amyl phenol, and *Cardolite 627*, which is a condensation polymer of formaldehyde and the phenolic constituents of cashew-nut-shell oil (cardanol).

The red-scale test insects were reared on fresh grapefruits of varying degrees of maturity, from half-grown fruit to mature fruit, depending on the time of year of the tests. The newly emerged young crawlers were brushed from heavily infested squash onto the grapefruits and kept in a room in which the temperature was held at 78° F. Under these conditions the insects reached maturity in approximately 40 days (Lindgren 1938), at which time they were ready for treatment.

The red-scale-infested grapefruits were then placed on a turntable and subjected to a continuous stream of spray during two revolutions of the turntable, a period of about 4.5 seconds. The laboratory precision power sprayer used in these experiments was built to resemble, in performance, as far as practicable, the large power sprayers used in field work. The sprays were applied at 300 pounds pressure. A three sixty-fourths inch disk was used in the nozzle, which was held 51 inches from the fruit during the spraying.

After the infested grapefruits had been sprayed, they were placed in a room maintained at a temperature of about 76° F., and a relative humidity of 40 to 60 per cent, and were kept there for three weeks. By the end of this period, the scale insects that had succumbed to the treatment had become sufficiently desiccated and discolored to permit the mortality determinations.

In making the mortality counts, only the scales situated on a delimited equatorial region of the fruit were examined, and only those scales separated from one another by at least the width of a scale (approximately 1.5 millimeters) were counted. The reason for this procedure is that the effectiveness of an oil spray has been found to be inversely proportional to population density. Scales draw oil from the surface of the fruit immediately adjacent to their bodies, and if they are

[1] Paper No. 532, University of California Citrus Experiment Station, Riverside, California.

[2] The authors wish to express their appreciation to Dr. Walter Ebeling for his many valuable suggestions and for his review and criticism of the manuscript.

[3] An emulsive spray oil is one which contains usually about 1 per cent of an oil-soluble emulsifier, which greatly reduces the interfacial tension between oil and water.

[4] A straight oil is one to which no solute has been added.

situated too closely together, there is less oil available per scale for any given amount applied per unit area. Discrepancies caused by population density and by uneven age distribution have therefore been eliminated by the laboratory method described in the present paper. Statistical evaluation showed that differences of 4 per cent or more between treatments were significant.

To simulate field conditions as nearly as possible, it seemed desirable to use the same dosage of light-medium oil (1.75 per cent) in some of the laboratory experiments (Tables 1, 2, and 4) as is generally used in the field. To do this under laboratory conditions without getting 99 to 100 per cent kill of scale, the oil deposit had to be controlled by shielding the fruit so that only a small section of the spray stream was directed onto the fruit surface.

A series of test spray treatments employing the above method showed that it was possible to duplicate results very accurately. Eight infested fruits were used in each test, and three replications of each treatment were made. The results shown in the following tables are therefore the average of three separate tests.

The amount of oil deposited on the sprayed grapefruits was determined by washing the oil from sample fruits and determining, by a gravimetric method, the amount of oil removed per unit of fruit surface. After considerable preliminary work, the following procedure was found to be satisfactory.

Four grapefruits were arbitrarily chosen for a sample. The fruits were sprayed with the oil and placed on wire racks on a table near the spray equipment. The evaporation of the water from the fruit was hastened with the aid of a current of air from a 12-inch electric fan, and took approximately an hour. Each fruit was placed in a funnel 6 inches in diameter and the oil was "stripped" from it with a fairly fine stream of petroleum ether, dispensed from a wash bottle at the rate of 1 millimeter per second, at a definite and constant air pressure. The tip of this funnel was placed in a smaller funnel, 2 inches in diameter, containing a filter paper and having a stem small enough in diameter so that it would enter the neck of a Babcock milk-test bottle.

As the oil was "stripped" from the fruits, the washings were filtered into previously weighed milk-test bottles. The filter paper was thoroughly washed with ether, and all washings were combined with the filtrate. The milk-test bottles containing the filtrates were placed in a water bath for ½ hour, at a temperature of 40° C., and the ether was drawn off by suction. The bottles were centrifuged at a

Table 1.—Effectiveness of derris extractives when dissolved in n-butyl phthalate and added to spray oil used against the California red scale.

Material[1]	Derris Extractives in Oil-Toxicant Solution, Per Cent by Weight	Oil Deposit on Fruit Surface (Mg./1000 Cm.²)	Per Cent Kill[2]
Straight (tank-mix) oil	0.0	66	62
Straight oil; plus *n*-butyl phthalate, 1 part to 7 parts oil	0.0	73	60
Straight oil; plus *n*-butyl phthalate, with 5 per cent derris extractives, 1 part to 31 parts oil	0.18		75
Straight oil; plus *n*-butyl phthalate, with 5 per cent derris extractives, 1 part to 15 parts oil	0.35	73	91
Straight oil; plus *n*-butyl phthalate, with 5 per cent derris extractives, 1 part to 7 parts oil	0.7		97
	0.7		97
Emulsive oil	0.0	56	61
Emulsive oil; plus *n*-butyl phthalate, 1 part to 7 parts oil	0.0	58	61
Emulsive oil; plus *n*-butyl phthalate, with 5 per cent derris extractives, 1 part to 31 parts oil	0.18		80
Emulsive oil; plus *n*-butyl phthalate, with 5 per cent derris extractives, 1 part to 15 parts oil	0.35	60	93
Emulsive oil; plus *n*-butyl phthalate, with 5 per cent derris extractives, 1 part to 7 parts oil	0.7		98

[1] Light-medium oil, 1.75 per cent concentration, used in all tests. For further description of oil, see text p. 567.
[2] Total of 45,655 adult female red scales examined.

Table 2.—Effectiveness of ground cube root when soaked in spray oil used against the California red scale.

MATERIAL[1]	ROTENONE PLUS DEGUELIN IN OIL, PER CENT BY WEIGHT[2]	OIL DEPOSIT ON FRUIT SURFACE (MG./1000 CM.²)	PER CENT KILL[3]
Straight (tank-mix) oil	0.0	63	57
Straight oil plus ground cube root, 3.9 per cent	0.16	63	95
Straight oil plus ground cube root, 7.8 per cent	0.25		96
Straight oil plus ground cube root, 15.6 per cent	0.30	63	98
Emulsive oil	0.0	56	58
Emulsive oil plus ground cube root, 3.9 per cent	0.21	59	95
Emulsive oil plus ground cube root, 7.8 per cent	0.40		97
Emulsive oil plus ground cube root, 15.6 per cent	0.55	61	97

[1] Light-medium oil, 1.75 per cent concentration, used in all tests. For further description of oil, see text p. 567.
[2] The concentration of rotenone plus deguelin was assumed to correspond approximately to the concentrations obtained by Ebeling *et al.* (1944) in colorimetric analyses.
[3] Total of 35,664 adult female red scales examined.

temperature of 60° C. for 10 minutes, to insure complete dissipation of the ether. The bottles were then cooled to room temperature and weighed. The oil was computed as milligrams per 1000 square centimeters of fruit surface, determined photoelectrically. Statistically it has been shown that a difference between means of 10 milligrams per 1000 square centimeters of fruit surface is highly significant.

EXPERIMENTAL RESULTS.—The effectiveness of derris extractives when dissolved in *n*-butyl phthalate and added to spray oil used against the red scale is shown in table 1. The data show clearly the relation of concentration of derris extractives to scale kill. The effect of the derris extractives on red scale is apparently the same whether added to a tank-mix oil containing blood-albumin spreader, or to an emulsive oil in which glyceryl dioleate is the emulsifier. It should be noted, however, that the spray containing the emulsive oil deposited less oil on the grapefruits.

In table 2 are given the results obtained from the use of ground cube root (200-mesh, and containing 4.3 per cent rotenone) soaked in oil for 20 minutes and sprayed on red scale. The increase in kill with increased percentages of the ground root is very evident, indicating that the toxic agent or agents in the root are extracted by the oil. There appears to be no difference between the tank-mix type of oil and the emulsive type, so far as insecticidal effectiveness is concerned, although, according to Ebeling *et al.* (1944), the emulsive spray oil is more efficient in extraction of rotenone plus deguelin.

Table 3.—Effectiveness of derris extractives when dissolved in various solvents and added to spray oil used against the California red scale.

MATERIAL[1]	DERRIS EXTRACTIVES IN OIL-TOXICANT SOLUTION, PER CENT BY WEIGHT	OIL DEPOSIT ON FRUIT SURFACE (MG./1000 CM.²)	PER CENT KILL[2]
Emulsive oil, without toxicant	0.00	31	28
Emulsive oil plus 5 per cent derris extractives in *n*-butyl phthalate	0.51	31	95
Emulsive oil plus 5 per cent derris extractives in diamyl phenol	0.51	27	76
Emulsive oil plus 4.2 per cent derris extractives in *Cardolite 627*	0.50	34	78
Emulsive oil plus 5 per cent derris extractives in 2-(4-tertiary-butylphenoxy) ethanol	0.51	19	16

[1] Light-medium oil, 0.5 per cent concentration, used in all tests. For further description of oil see text p. 567.
[2] Total of 9898 adult female red scales examined.

Table 4.—The effect of heating derris extractives in the mutual solvent before addition to spray oil used against the California red scale.

Test Number, Material,[1] and Procedure	Derris Extractives in Oil-Toxicant Solution, Per Cent by Weight	Per Cent Kill[2]
1. Emulsive oil, without toxicant	0.0	60
2. Emulsive oil plus 5 per cent derris extractives in *n*-butyl phthalate. Toxicant heated in ¼ of solvent, ½ minute at 110° C.; remainder of solvent then added to cool solution rapidly	0.7	98
3. Emulsive oil plus 5 per cent derris extractives in *n*-butyl phthalate. Toxicant heated in ¼ of solvent, 1 minute at 100° C.; remainder of solvent then added to cool solution rapidly	0.7	97
4. Emulsive oil plus 5 per cent derris extractives in *n*-butyl phthalate. Toxicant heated in total amount of solvent, 3 minutes at 60° C.; cooled gradually	0.7	97
5. Same as test 2, but with diamyl phenol as mutual solvent	0.7	96
6. Same as test 3, but with diamyl phenol as mutual solvent	0.7	96
7. Same as test 4, but with diamyl phenol as mutual solvent	0.7	96

[1] Light-medium oil, 1.75 per cent concentration, used in all tests. For further description of oil, see text p. 567.
[2] Total of 36,625 adult female red scales examined.

Again, the emulsive oil spray deposited less oil than the straight (tank-mix) oil, but as the percentage of cube root was increased, the two types of spray became more similar in their oil-depositing properties, until with the addition of 15.6 per cent ground cube root, the oil-depositing efficiency of the two sprays was about the same. The oil-depositing properties of the emulsive-oil spray increased progressively with increasing amounts of cube root.

Results of tests using various mutual solvents with derris extractives in spray oil against the red scale (Table 3) show that *n*-butyl phthalate was the most effective, even though only a portion of the extractives was held in true solution in the solvent when it was added to the oil, the remainder being in suspension. When 2-(4-tertiary-butylphenoxy) ethanol was used as the solvent for the derris extractives, the oil deposit was reduced by 39 per cent, as compared with that of oil alone, and the insecticidal effectiveness of the oil was reduced despite the addition of the extractives.

Another series of tests was conducted to determine whether there was any relation between the temperature at which the derris extractives were dissolved in the solvents, before addition to the spray oil, and the insecticidal effectiveness of the spray

Table 5.—The effect of aging derris extractives in mutual solvent solution before addition to spray oil used against the California red scale.

Test Number, Material,[1] and Procedure	Derris Extractives in Toxicant Solution, Per Cent by Weight	Oil Deposit on Fruit Surface (Mg./1000 Cm.[2])	Per Cent Kill[2]
1. Emulsive oil, without toxicant	0.0	58	74
2. Emulsive oil plus 5 per cent derris extractives in *n*-butyl phthalate; toxicant solution made 6 months before using	0.51		80
3. Emulsive oil plus 5 per cent derris extractives in *n*-butyl phthalate; toxicant solution made 24 hours before using	0.51	44	90
4. Same as test 2, but with diamyl phenol as mutual solvent	0.51		92
5. Same as test 3, but with diamyl phenol as mutual solvent	0.51	39	91
6. Same as test 2, but with di-isobutyl ketone as mutual solvent	0.51		92
7. Same as test 3, but with di-isobutyl ketone as mutual solvent	0.51	52	96

[1] Light-medium oil, 0.75 per cent concentration, used in all tests. For further description of oil, see text p. 567.
[2] Total of 19,200 adult female red scales examined.

Table 6.—The effect of aging ground cube root in light-medium emulsive oil on its toxicity to adult red scale.

MATERIAL[1] AND PROCEDURE	OIL DEPOSIT ON FRUIT SURFACE (Mg./1000 Cm.²)	PER CENT KILL[2]
Emulsive oil, without toxicant	53	81
Emulsive oil plus 3.9 per cent ground cube root soaked in oil for 12 hours; filtered; aged for 6 months before using	49	95
Emulsive oil plus 3.9 per cent ground cube root soaked in oil for 6 months before using; not filtered	53	96
Emulsive oil plus 3.9 per cent ground cube root soaked in oil for 12 hours before using; filtered		94
Emulsive oil plus 3.9 per cent ground cube root soaked in oil for 12 hours before using; not filtered		98

[1] Light-medium oil, 0.75 per cent concentration, used in all tests. For further description of oil, see text p. 567.
[2] Total of 9650 adult female red scales examined.

against the red scale (Table 4). The data show that when the derris extractives were dissolved in a portion of the required amount of solvent, at 110° C., and the remainder of the solvent was added to cool the solution rapidly, the toxicant was very little if any more effective than when the extractives were dissolved in the entire amount of mutual solvent, at 60° C., and cooled gradually.

The aging of derris extractives in various mutual solvents, before addition to the spray oil, appeared to have some effect on the toxicity of the spray to the red scale (Table 5). The extractives were dissolved in the mutual solvents, placed in stoppered bottles, and held in the laboratory away from any direct light. After 6 months' storage, the extractives in *n*-butyl phthalate and in di-isobutyl ketone had lost some of their toxicity, but the loss was not so great with di-isobutyl ketone as with *n*-butyl phthalate. There was practically no difference in the toxicity of derris extractives aged in diamyl phenol as mutual solvent 6 months or only 24 hours.

Aging of ground cube root in a light-medium emulsive oil appeared to have little or no effect on toxicity (Table 6). The results indicate that 12 hours of soaking in the oil was sufficient for extraction of the toxic material from the ground root. Whether this had been done 6 months or 12 hours previous to spraying seemed to have little or no effect on the kill of the red scale.

Another series of tests was conducted to

Table 7.—Effect of length of time of soaking ground cube root in mineral seal oil or kerosene on its toxicity to adult red scale.

MATERIAL[1] AND PROCEDURE	PER CENT KILL[2]
Mineral seal oil, without toxicant	86
Mineral seal oil; 4 per cent ground cube root added directly to oil-spray mixture in spray tank	97
Mineral seal oil plus 4 per cent ground cube root stirred into the oil just before the mixture was poured into the spray tank	98
Mineral seal oil plus 4 per cent ground cube root soaked in the oil for 5 minutes before pouring into the spray tank	99.8
Mineral seal oil plus 4 per cent ground cube root soaked in the oil for 10 minutes before pouring into the spray tank	99
Mineral seal oil plus 4 per cent ground cube root soaked in the oil for 20 minutes before pouring into the spray tank	99.7
Kerosene, without toxicant	42
Kerosene; 4 per cent ground cube root added directly to spray mixture in spray tank	85
Kerosene plus 4 per cent ground cube root stirred into the oil just before the mixture was poured into the spray tank	97
Kerosene plus 4 per cent ground cube root soaked in the oil for several hours before pouring into the spray tank	98

[1] Mineral seal oil, 1 per cent concentration; kerosene, 3 per cent concentration. For further description of these oils, see text p. 567.
[2] Total of 21 535 adult female red scales examined.

determine the length of time the ground cube root had to soak in mineral seal oil, or in kerosene, before the toxic materials were extracted. The results are given in table 7. It appears that if the root is added to the oil or kerosene just before the mixture is poured into the spray tank, practically the full value of the toxicant is obtained, but if the ground cube root is added directly to the oil-spray mixture in the spray tank, the full value of the toxicant is not obtained. The difference in the effect of the manner of soaking is somewhat greater when the ground cube root is added to the kerosene than when added to the mineral seal oil.

SUMMARY.—A laboratory method has been devised to make possible rapid and accurate determinations of small differences in the effectiveness of oil sprays against the California red scale, *Aonidiella aurantii* (Mask.). Three grades of oil were used in tests with and without various concentrations of derris extractives (30 per cent rotenone) or of ground cube root (4.3 per cent rotenone), with various mutual solvents.

When derris extractives were incorporated into a light-medium spray oil, with *n*-butyl phthalate as mutual solvent, there was a progressive increase in the toxicity of the oil to the red scale as the concentration of the derris extractives was increased from 0 to 0.7 per cent. Whether the oil was straight oil used as a tank mixture with blood-albumin spreader, or an emulsive oil containing 1 per cent glyceryl dioleate as emulsifier, made no difference in the insecticidal effectiveness of the spray, although the emulsive-oil spray deposited less oil on the grapefruits.

Ground cube root (200-mesh) soaked in straight oil or emulsive oil was about as effective as the derris extractives incorporated into the oil by means of mutual solvents.

Mutual solvents which reduced the oil-depositing efficiency of the spray also reduced its insecticidal efficiency. When 2-(4-tertiary-butylphenoxy) ethanol was used, the insecticidal effectiveness of the spray was reduced below that of oil alone, despite the addition of derris extractives.

When the derris extractives were dissolved in a portion of the required amount of mutual solvent at 110° C., and the remainder was added to cool the solution rapidly, the toxicant was found to have no greater insecticidal effectiveness than when the extractives were dissolved in the entire amount of mutual solvent, at 60° C., and cooled gradually.

The result of 6 months of aging on the insecticidal effectiveness of derris extractives in *n*-butyl phthalate, di-isobutyl ketone, and diamyl phenol was determined. The result of aging in reducing the effectiveness of the solution was greatest when the extractives were dissolved in *n*-butyl phthalate, and was only slight when the extractives were dissolved in di-isobutyl ketone; with diamyl phenol practically no deterioration occurred.

When the toxic ingredients of cube root were extracted by soaking the root in light-medium emulsive spray oil, no reduction in the effectiveness of the oil was caused by 6 months of aging. Twelve hours of soaking of the ground cube root in the oil appeared to result in complete extraction of the toxic ingredients, for more prolonged soaking resulted in no further increase in toxicity. If the cube root is added directly to the oil spray in the spray tank, the insecticidal effectiveness of the spray is not so great as when the cube root is stirred into the oil before the oil is poured into the spray tank.—6-30-45.

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New Insecticides for Chicken Lice Control

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Rotenone is probably the most efficient and safest general lousicide known, however, it has always been expensive and is now under strict wartime allocation. Pyrethrum, while lacking the residual properties of rotenone, has been very widely employed, largely because it gives a quick knockdown and is relatively non-toxic to warm blooded animals. Pyrethrum for civilian use is also restricted due to the requirements of the armed services. The urgent need for available substitutes for rotenone and pyrethrum has stimulated search for new toxicants. This investigation is the first step in developing effective insecticides and methods for the control of lice on chickens and cattle. The most promising compounds will be tested later on cattle. One of the most urgent needs of the poultry and livestock industries is a louse killing agent which is relatively non-toxic to vertebrates, is easily applied, cheap, readily available and possesses sufficient residual properties so that one application is adequate.

HISTORICAL ACCOUNT.—The earliest materials employed, in many instances, were of questionable value and no references to this early literature are indicated. Successful control of chicken lice had its inception with the announcement by Bishopp and Wood (1917) that sodium fluoride was an effective and inexpensive remedy. The use of mercurial ointment antedates the introduction of sodium fluoride, Pearl *et al.* (1915) and Lamson (1917) but it has never been popular and is now seldom used. Both insecticides have disadvantages. Sodium fluoride is irritating to the operator and potentially toxic to vertebrates, while mercurial ointment is apparently detrimental to the fertility of both eggs and birds (Deakin & Robertson 1933). Abbott (1919) published on the use of naphthalene and the year following summarized in a bulletin his results on testing a great number of louse killing agents, including sprays and dips of "hydrocarbon oils, phenols, nitrobenzol, coal tar, wood tar distillate, pyridine bases and soaps." His final conclusions were that mercurial ointment, sodium fluoride, sulfur and pyrethrum were the most successful. Naphthalene has been a common ingredient of louse powders but is low in toxicity and dangerous when applied to the chicken in excess of 10 per cent.

Just when pyrethrum was first used against chicken lice is not known, however it was apparently a constituent of louse powders when Osborn (1896) published his monograph on insects affecting domestic animals. Derris gained wide acceptance following the work of McIndoo *et al.* (1919) and Wells *et. al* (1922) when they found it a safe and effective lousicide. Later the work of Marcovitch (1924, 1926) and Parish (1943) showed sodium fluosilicate to be comparable to sodium fluoride in toxicity as dips or dusts. Nicotine sulfate was first used successfully as a roost paint in 1928 by a California poultryman. Carpenter (1931), Bishopp & Wagner (1931) and others verified his observations. This method rapidly came into widespread use since entire flocks could be treated simultaneously, thus eliminating the handling of individual birds. Although one of our most popular louse remedies it is not, effective against head lice and repeated applications are necessary to control other species of chicken lice. It is a potential hazard to the operator and is particularly toxic to young birds.

Many once believed that internal medication was effective for louse control. However, Parman *et al.* (1928) obtained negative results in the oral administration of numerous compounds and proprietary louse remedies. More resently Emmel (1937, 1938, 1942) and Creighton *et al.* (1943) found dusting sulfur promising when used in and around poultry houses and in feed. The latter work indicated, however, that relatively large quantities must be used for effective control. The necessity of frequent applications of large quantities of sulfur discourages this practice. There are some records of skin injury to birds when large quantities of sulfur are applied. Telford (1944) found DDT 0.5 to 4 per cent and sodium fluoride 33 per cent in pyrophyllite to be effective against shaft and body lice.

The above is a brief recapitulation on

[1] Entomologist, Dr. Hess & Clark, Inc.

the development of the more commonly used lousicides. For a more extensive list of references the reader is referred to Benbrook (1943).

METHODS AND MATERIALS.—The chickens employed were all from a commercial flock of 30-month-old White Leghorn hens. They were naturally infested with lice of the following species: body louse, *Eomenacanthus stramineus* (Nitzsch); shaft louse, *Menopon gallinae* (L.); and fluff louse, *Goniocotes hologaster* Nitzsch. These occurred in that order of abundance.

The chemicals employed were all known to be active insecticides or inert materials of the nature ordinarily used as diluents in preparing insecticidal dusts. They were obtained from the usual commercial sources, and the formulae prepared from the commercial materials that were obtained separately except where otherwise noted. Miscellaneous mechanical equipment included a device for restraining the birds while dusting and making observations and a salt-shaker-type applicator for dusting individual birds.

Since the louse population varied widely on several birds from the same flock, the chickens used were examined before treatment and all birds showing fewer than 50 lice were discarded. The amount of dust applied to each bird was determined by weighing the applicator both before and after use. Birds under experiment were confined in separate cages, so that extraneous contamination was prevented.

The efficacy of the treatments was determined by repeated examinations. Treated birds were generally kept under observation for 5 to 7 days to ascertain whether or not reinfestation from hatching of the eggs occurred. A preparation which destroys all lice on a treated bird and which prevents reinfestation for 5 to 7 days exhibits, for purposes of this paper, a "residual effect" regardless of whether that effect is ovicidal or by a residue of active insecticide that remains in the feathers and destroys newly hatched lice as they emerge. In a few instances, the duration of the residual effect was measured by releasing marked birds in an infested flock and catching those individuals for re-examination at frequent intervals. Four to 6 control birds were maintained in laying batteries while experiments were in progress to enable the investigator to detect adventitious decline in louse populations.

EXPERIMENTAL RESULTS.—The results obtained in testing 37 mixtures are included in table 1, where it may be seen that demonstrable residual effects were exhibited by DDT, from 0.5 to 4 per cent; sodium fluoride, 33 per cent; *Kryocide* (cryolite) 30 per cent; derris (with 5 per cent rotenone), 10 per cent; the mixtures containing sulfur and the tetramethyl thiouram salts. The quickest acting powders were those containing *Lethane B-71*, 10 per cent; *Thanite*, 5 per cent *NH Dust*, 10 per cent; diphenyl, 5 per cent; o-nitrodiphenyl, 10 per cent; pyrethrins, 0.066 per cent; derris (with 5 per cent rotenone), 10 per cent; and phenothioxine, 10 per cent. These latter formulations, however, with the exception of derris, exhibited no residual properties. When 30 per cent micronized wettable sulfur was added to the quick-acting powders, the mixtures retained their quick killing properties and were residual in action. Pyrethrum Formula No. 1 was quick acting and had good residual properties. However, its toxicity decreased considerably when it was diluted to half and three-fourths with *Pyrax*.

Experiments to test the duration of the residual effects of DDT, sodium fluoride and micronized wettable sulfur under conditions permitting reinfestation were conducted by returning treated birds to pens of infested birds. Six birds treated with DDT, 4 per cent in *Pyrax*, had louse infestations approaching their original population within 30 to 34 days. Six birds similarly treated with sodium fluoride, 33 per cent in *Pyrax*, acquired louse populations more rapidly than the birds treated with DDT, 4 per cent. For comparison, in 17 days, the 6 birds treated with DDT harbored a total of eight body lice and one shaft louse, while the 6 treated with sodium fluoride harbored a total of 15 body lice and 34 shaft lice. Fluff lice were not involved in either experiment. A longer residual effect, particularly on body lice, was noticed when micronized wettable sulfur was employed. Four birds deloused with sulfur and introduced into the infested flock were all free of body lice after 24 days exposure; during that time, however, the shaft lice had built up infestations almost to their original levels.

Table 1.—Results of dusting individual birds.

Trial No.	Formula	Grams per Bird	Number of Birds	Observation Period	Species of Louse			Residual Effect	Effect of Treatment on Lice
					Body	Shaft	Fluff		
1	DDT 4% in *Pyrax*	6.2	7	30 days	x	x		Yes	Complete kill within 28 hrs.
2	DDT 2% in *Pyrax*	7.2	2	30 days	x	x		Yes	Complete kill within 28 hrs.
3	DDT 1% in *Pyrax*	8.0	1	30 days	x	x		Yes	Complete kill within 28 hrs.
4	DDT 0.5% in *Pyrax*	11.8	4	30 days	x	x		Yes	Complete kill within 28 hrs.
5	DDT 0.25% in *Pyrax*	6.5	4	52 hrs.	x	x		—	Very poor kill.
6	DDT 0.125% in *Pyrax*	6.9	4	52 hrs.	x	x		—	Very poor kill.
7	Sodium fluoride 33% in *Pyrax*	7.8	6	30 days	x	x		Yes	Complete kill within 52 hrs.
8	Sodium fluoride 15% in *Pyrax*	8.4	4	4 days	x	x		Yes	Two shaft lice remaining at 4 days.
9	*Lethane B-71*—10% in *Pyrax*	8.2	4	7 days	x	x		No	Three shaft lice remaining at 4 hrs.
10	*Lethane B-71*—5%, mic. wet. sulfur 30% in *Pyrax*	5.1	4	15 days	x	x	x	Yes	Complete kill within 26 hrs.
11	Phenothioxine 10% in *Pyrax*	6.3	12	11 days	x	x	x	No	Five shaft, 1 body louse remaining at 48 hrs.
12	Phenothioxine 10% in *Pyrax* (fusion mixture)	6.5	4	11 days	x	x	x	No	Complete kill within 24 hrs.
13	Phenothioxine 10% in bentonite	5.5	4	11 days	x	x	x	No	Complete kill within 24 hrs.
14	Phenothioxine 10% in bentonite (fusion mixture)	5.5	4	11 days	x	x	x	No	Complete kill within 24 hrs.
15	Phenothioxine 5%, mic. wet. sulfur 30% in *Pyrax*	6.5	4	15 days	x	x	x	Yes	Complete kill within 24 hrs.
16	*Genicide* (xanthone) 30% in *Pyrax*	6.8	4	9 days	x	x	x	No	Six body, 5 fluff lice remaining at 28 hrs.
17	*NH Dust* 10% in *Pyrax*	9.4	4	5 days	x	x		No	Complete kill within 28 hrs.
18	*NH Dust* 5%, mic. wet. sulfur 30% in *Pyrax*	7.0	4	15 days	x	x	x	Yes	Three shaft lice remaining at 26 hrs. Complete eventual kill.
19	*Thanite* 5% in *Pyrax*	9.7	4	9 days	x	x		No	Complete kill within 4 hrs.
20	*Thanite* 5%, mic. wet. sulfur 30% in *Pyrax*	5.1	4	15 days	x	x	x	Yes	Complete kill within 26 hrs.
21	Diphenyl 5%, mic. sulfur 30%, bentonite 7.5% in *Pyrax*	7.6	4	15 days	x	x	x	Yes	Nine body, 8 shaft, 5 fluff lice remaining at 26 hrs. Complete eventual kill.
22	Diphenyl 2%, *AR 50*[1] 5% in *Pyrax*	11.2	4	5 days	x	x		No	Poor kill.
23	o-Nitrodiphenyl 10% in *Pyrax*	11.1	4	30 days	x	x		No	Complete kill within 5 hrs.
24	*Kryocide* (cryolite) 30% in *Pyrax*	7.9	4	30 days	x	x		Yes	Two body lice remaining at 5 days.
25	Mic. wettable sulfur	10.4	4	30 days	x	x		Yes	Complete kill within 5 days.
26	Orthophenylphenate 10% in *Pyrax*	10.9	1	4 days	x	x		—	No control.
27	Nicotine 0.5% (*Black Leaf 155*) in *Pyrax*	6.3	6	30 days	x	x		No	Complete kill of body lice within 4 hrs. Poor kill of shaft lice.
28	Tetramethyl thiouram-disulfide 10% in *Pyrax*	10.1	4	6 days	x	x		Yes	One shaft louse remaining at 3 days.
29	2% conc. of tetramethyl thiouram-monosulfate 90% and tetramethyl thiouram-disulfide 10% in *Pyrax*	7.7	4	6 days	x	x		Yes	Complete control within 28 hrs.
30	2,4 dinitro-o-cyclohexyl phenol 5% in *Pyrax*	9.3	4	6 days	x	x	x	No	Three shaft lice remaining at 4 hrs Stains hands and feathers.
31	Sabadilla 10%, hydrated lime 10% in *Pyrax*	7.0	2	3 days	x	x		No	Very poor control.
32	Derris (5% rotenone) 10% in *Pyrax*	6.1	4	8 days	x	x		Yes	Complete kill within 24 hrs.
33	2,4 dinitroanisole 2% in *Pyrax*	9.0	4	12 days	x	x	x	—	No control.
34	2,4 dinitroanisole 2%, *IN-930* 2% in *Pyrax*	7.3	4	12 days	x	x	x	—	No control.
35	Pyrethrum formula I[2]	8.5	4	14 days	x	x	x	Yes	Complete kill within 4 hrs.
36	Pyrethrum formula II	9.2	4	8 days	x	x		—	Five body lice remaining at 8 days.
37	Pyrethrum formula III	8.2	4	7 days	x	x		No	Fourteen body, 3 shaft lice remaining at 7 days.

[1] *AR 50* is a polymethylated naphthalene.
[2] A proprietary louse powder containing: pyrethrins 0.066%, sulfur 30%, naphthalene 5%, petroleum hydrocarbons 0.45%, inert 64.48%. Formulae II and III are ½ and ¼ dilutions respectively of the above with *Pyrax*.

Throughout these tests the louse populations of the control birds remained relatively constant.

SUMMARY AND CONCLUSIONS.—Thirty-seven louse powders were tested with a salt-shaker type applicator on 149 louse-infested chickens. Those acting relatively quickly and demonstrating residual properties were: DDT, 0.5 to 4.0 per cent; derris (with 5 per cent rotenone), 10 per cent; tetramethyl thiouram salts, 2 and 10 per cent; and powders containing 30 per cent sulfur mixed with one of the following: *Lethane B-71*, 5 per cent; *Thanite*, 5 per cent; phenothioxine, 5 per cent; *NH Dust*, 5 per cent; diphenyl, 5 per cent; and pyrethrins, 0.066 per cent. Sodium fluoride 33 per cent, *Kryocide* (cryolite) 30 per cent and micronized wettable sulfur were highly effective but slow to act.

Duration of insecticidal potencies of some of the more promising mixtures was determined by placing chickens, previously deloused, into an infested flock and later removing them for examination. Six birds dusted with DDT, 4 per cent, had louse infestations approximating their original population within 30 to 34 days. Residual effect of longer duration was

observed with 4 birds dusted with micronized wettable sulfur while less residual effect was observed on 6 birds dusted with sodium fluoride, 33 per cent.

Those mixtures which were relatively quick acting but demonstrated no residual properties when employed as sole toxicants were: *Lethane B-71*, 10 per cent; phenothioxine, 10 per cent; *NH Dust*, 10 per cent; *Thanite*, 5 per cent; and o-nitrodiphenyl, 10 per cent. The following gave unsatisfactory results: Sodium fluoride, 15 per cent; nicotine (*Black Leaf 155*), 0.5 per cent; DDT, 0.25 and 0.125 per cent; *Genicide* (xanthone), 30 per cent; 2,4 dinitro-o-cyclohexyl phenol, 5 per cent; sabadilla, 10 per cent; 2,4 dinitroanisole, 2 per cent; a mixture of 2,4 dinitroanisole, 2 per cent and *IN-930* (N-isobutylundecylenamide), 2 per cent; orthophenylphenate, 10 per cent; a mixture of diphenyl, 2 per cent and *Velsicol AR-50*, 5 per cent; and 2 dilutions to 0.033 and 0.016 per cent of pyrethrins in a proprietary louse powder.[1]—6-18-45.

[1] The author acknowledges the active cooperation of the following commercial concerns for supplying the insecticides and subsidiary materials used in this investigation: Rohm & Haas Company, Micronizer Processing Company, Geigy Company, Inc., General Chemical Corp., John Powell & Company, Hercules Powder Company, E. I. du Pont de Nemours & Company, Inc., Pennsylvania Salt Manufacturing Company, Inc., Tobacco By-Products & Chemical Corp., American Cyanamid & Chemical Corp., McConnon & Company, Velsicol Corp., and Verona Chemical Corp. Special mention is also made of the help of Dr. Alfred Weed and Dr. George Hartz of John Powell & Company for making an analysis of pyrethrins. Dr. C. J. Weinman, Special Research Assistant, Illinois Natural History Survey, in cooperation with the Monsanto Chemical Company and Mr. W. W. Allen and Mr. D. K. Ballman of Dow Chemical Company prepared and supplied several formulations.

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A. F. Swain, who worked for two years with the Quartermaster Corps is returning to his native State of California on November 1. He will be in charge of the Insecticide Department of the Pittsburg Chemical Company, 3100 East 26th Street, Los Angeles 23, Calif.

Food Preferences of the Firebrat

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Food preferences of the firebrat, *Thermobia domestica* Pack., have received some attention in recent years. Wakeland & Waters (1931) recommended a food composed of ground oatmeal, sugar and salt. Spencer[1] recommended flour as the most suitable material for a firebrat food. Back (1921) recommended starch paste. In conversations with pest control operators, it was found that many have used commercial pancake flours as a bait with satisfactory results.

In one room of our building in which firebrats had become very numerous, the writer placed a dozen glass bottle traps baited with various types of food believed to be attractive to firebrats. In these experiments the location of the trap determined the number of insects caught. Traps without a food that were favorably located caught more firebrats than traps less favorably located that contained food. This experiment indicated that firebrats are not attracted from a distance by food, and that any poisoned food to be effective in the control of firebrats should be placed where these insects are seen or are likely to breed. It also raised the question, are firebrats capable of food selection?

Procedure.—When it was found that the number of firebrats caught in traps was related to trap location rather than food, the following procedure was instituted to find out if firebrats were capable of food selection and if they have any food preferences when a number of foods are equally available.

Glass tubing three-eighths inch in diameter was cut into three-quarter inch pieces. Each piece was stoppered with a small cork. The diameter was arbitrarily chosen, but a small size was necessary in order to weigh conveniently to the nearest tenth of a milligram. The corks of these small vials or food tubes were numbered; before and after each test the vials were enclosed in a glass covered box (Fig. 1). There were six tubes for each food under test. Five were used to evaluate the food and the sixth to give a check on the change in weight due to humidity changes during the period of test.

[1] Unpublished thesis, 1924.

In each of 10 blocks 7.5 inches square from 1 inch lumber a circular groove 7 inches in diameter, one-quarter inch deep and one-eighth inch wide, was cut. This groove was used to hold a 2-inch celluloid retaining wall in place. It is impossible for firebrats to climb a clean, perpendicular celluloid wall. In the space enclosed by the groove, 13 evenly spaced depressions were made with a 1-inch steel

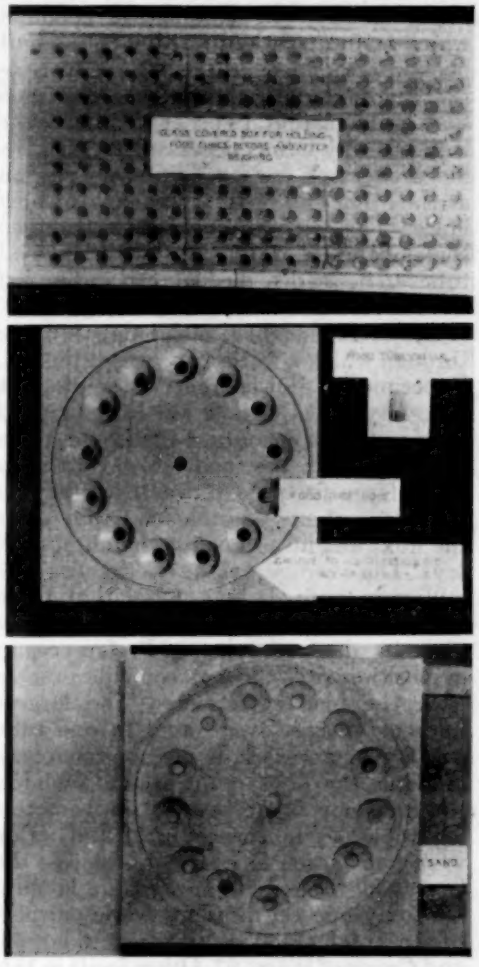

Fig. 1.—Top: Glass covered base for holding food material before and after exposure of the food to the firebrats. 2. Middle: Testing unit for evaluating attractiveness of foods to the firebrat. Bottom: One testing unit set up to determine the attractiveness of various foods.

drill on a drill press. The depressions at a minimum depth were one-eighth inch. From previous experience it was found necessary to have these depressions because the firebrat in feeding will often dig in the food, as a dog does in burying a bone, thus scattering the food. At the bottom of each of these depressions a three-eighths inch hole was made which, during the period of test, held the food tube. Each depression was painted with a medium heavy solution of acetone and celluloid which facilitated the brushing of the bait back into the food tubes after the test period but did not interfere with normal passage of the insects. In order to remove the tubes readily it was necessary to turn the block over and make a similar depression at the other end of the three-eighths inch holes. This second depression removed some of the sidewall and allowed the food tubes to be readily pushed into and pulled from the holes. In the center of each block (Fig. 1) a three-eighths inch hole was made through which a water tube was extended. Experiments showed that water was not necessary, and this hole was later plugged with cotton to encourage egg laying there rather than in the food. However, when using large firebrats it was necessary to sift the contents of each food tube after the final weight and count the number of eggs. The average weight of eggs was 0.37 milligram each. It was noted that there was a preference for certain baits as a place in which to oviposit. Preferences in oviposition sites did not coincide exactly with the food preferences. The largest number of eggs ever found in one tube was 25. As an example of the preferences of oviposition sites by the firebrat females, the following figures are taken from test 2 of table 2. Whole wheat bread and barley were not chosen as oviposition sites; the five food tubes containing karaya gum had only one egg present, while oatmeal had a total of 30 eggs, wheat flour 53, and *Cream of Wheat* 67. Other foods in this test contained a varying number of eggs between these figures.

Fifteen firebrats were confined to each block and allowed to feed undisturbed for 10 days in a constant temperature cabinet maintained at 80° F. ±2 and 50 per cent ±5 relative humidity. The 10 blocks were set up in two series of five each on a tray filled with sand. The sand allowed all of the tops of the food vials (Fig. 1) to be placed flush with the bottoms of the depressions which were made so that the firebrats could not kick the food from one food tube into another. At the end of the test the insects were removed and all food in each depression was brushed back into the tube with a camels-hair brush. The five replicates and the one control were weighed consecutively. The change in weight of the one control food and the number of eggs present in each food tube were taken into consideration in evaluating the baits under test. The amount of food eaten was used as a criterion of each food's attrativeness to the firebrat. All food tubes were thoroughly cleaned and refilled before additional tests were run.

Firebrats were reared on wheat flour at 100° F. ±2 and 50 per cent ±5 relative humidity, and were within 10 days of being the same age for any one series of tests. In culture jars the majority of eggs were deposited in cotton when this material was available to the adults. From a series of rearing jars the cotton containing eggs was removed every 10 days and placed in a clean jar. In this way it was possible to have insects of about the same age. The firebrats for any one test were from the same rearing jar. All tests were conducted at 80° F. ±2 and 50 per cent relative humidity ±5, which more closely approaches household conditions than the temperature at which the test insects were reared.

All baits were ground until they passed through a number 50 U. S. standard sieve. If particles were larger it was found that they were often carried away but not eaten by the insects.

EXPERIMENTAL RESULTS AND DISCUSSION.—Table 1 shows a summary of the foods found to be equal to or significantly better than wheat flour in attractiveness to the firebrat at the 1 per cent level (99:1). *Cream of Wheat* was found to be significantly better than wheat flour in all tests where they were compared except those two in which egg noodles were also present. This shows conclusively that every food has an influence on the reaction of the firebrats to the other foods present in the test and therefore only those foods in the same test can be compared. In tests 1 through 7 of table 1, a series of foods were evaluated in attractiveness to the firebrat. In test 8, wheat flour, oatmeal and *Cream of Wheat*, sometimes with salt or

Table 1.—Rating of 66 foods or combinations of foods in attractiveness to the firebrat when wheat flour is given the arbitrary figure of 100.[1]

Food	Test Number									
	1	2	3	4	5	6	7	8	9	10
Egg noodles					228[2,3]				548[2,3]	717[2,3]
Aunt Jemima ready-mix buckwheat pancake flour						498[3]				438[3]
Hoof meal						406[3]				430[3]
Aunt Jemima ready-mix pancake flour						346[3]				420[3]
Wheat flour 85%, powdered sugar 15%								377[2,3]		
Cream of Wheat 95%, powdered sugar 5%							276[2,3]			463[3]
Cream of Wheat		362[2,3]	386[3]	313[2,3]	122	505[3]	167[3]	267[3]		168
Sunnyfield ready-mix pancake flour	111									454[3]
Honey Mead graham crackers			266[4]							
Ballard's pancake flour						316[3]			151[4]	
Wheat flour 80%, powdered sugar 20%								222[3]		
Macaroni									216[3]	
Wheat	137[2,3]									280
Karaya gum	108	142[4]					183[3]			287[4]
Oatmeal 85%, salt 5%, sugar 10%								160		
Wheat flour 95%, powdered sugar 5%								152		
Rye bread									148	
White bread									141	
Dried whey						139				
Wheat 50%, granulated sugar 50%		122								
Wheat flour 90%, salt 10%								117		
Traganth gum		108								
Barley				108						
Faultless clothes starch						180				30
Macaroni					100					
Dried skim milk (used in livestock feed)			103						96	
Wheat flour	100	100	100	100	100	100	100	100	100	100
Wheat flour 50%, powdered sugar 50%		96								
Moldy fish meal									96	
Powdered dried whole eggs							95			
Rice	92									
Cocoa					87					
Grape Nut Flakes						81				
Wheat flour 25%, powdered sugar 75%		80								
Oatmeal 93%, sugar 4.7%, salt 2.3%								80		
Calf Manna (milk supplement for calves)							79			
Wheat flour 90%, salt 5%, sugar 5%								79		
Molasses beet pulp						77				
Wheat flour 95%, salt 5%								77		
Beef meal				75						
Friskies dog food				73						
Dried skim milk (ice cream manufacture)									72	
Egg albumen	68									
Blood meal		68								
Dried buttermilk				68						
Sunnyfield ready-mix pancake flour 50%, powdered sugar 50%		63								
Powdered sugar					60					
Wheat flour 80%, salt 20%								57		
Moldy wheat flour									50	
Moldy *Sunnyfield* ready-mix pancake flour									36	
Oats				46						
Tankage				41						

Table 1.—*Continued*

Food	Test Number									
	1	2	3	4	5	6	7	8	9	10
Soybean oil meal			40							
BY (used in livestock feeds)			38							
Horn meal				34						
Brewer's yeast				33						
Soybean meal, less than 1% oil			29							
Flake lac				27						
Corn meal						21				
Corn gluten			21							
Dried brewer's grain			20							
Corn			15							
Granulated sugar						14				
Soybeans			13							
Linseed oil meal			11							
Kosto-Freeze vanilla ice-cream mix						8				

[1] Foods found to be significantly inferior to wheat flour are listed in text.
[2] At the 1% level (99:1) significantly better than all other foods in that test.
[3] At the 1% level (99:1) significantly better than wheat flour.
[4] At the 5% level (19:1) significantly better than wheat flour.

sugar added, were evaluated. It is to be noted that the two oatmeal foods containing salt and sugar are not significantly better than wheat flour at the 5 per cent level, whereas *Cream of Wheat* and wheat flour containing 15 and 20 per cent sugar are significantly better than wheat flour. Note that the combination consisting of wheat flour 85 per cent, powdered sugar 15 per cent is significantly better at the 1 per cent level than all other foods in this test.

Moldy food is not very attractive to firebrats. Three of the four moldy foods evaluated in test 9 ranked lower, but not significantly lower, than wheat flour. If the difference had been 0.02 greater between wheat flour and moldy wheat flour, wheat flour would be significantly better at the 5 per cent level.

Test 10 is the re-evaluation of some of the foods most promising in attractiveness to the firebrat. Egg noodles are significantly (99:1) better than all other foods in this test. However, note that wheat flour 85 per cent, powdered sugar 15 per cent, is omitted.

In addition to the foods listed in table 1, the following foods were also tested but found to be significantly inferior at the 1 per cent level (99:1) to wheat flour. In test 1, oatmeal, fish meal, dried insects; corn starch; meat scraps, tapioca and alfalfa meal; in test 2, *Ann Page* vanilla pudding and bone gelatin; in test 3, debittered soybean flour, 5 per cent oil; in test 4, blood albumin and dried solubles; in test 5, wheat middlings, soda crackers, *Gerber's* strained oatmeal, *Sunseal* wheat paste, non-curling envelope glue, wheat bran and salt; in test 7, tragacanth gum, wheat germ, gum ghetti, apple pomace, gum arabic, locust bean gum and kelco gum; in test 9, moldy white bread and dried whey; in test 10, *Honey Mead* graham crackers.

Table 2 shows a summary of the food combinations tested and found equal to or better than the combination of wheat flour 85 per cent, powdered sugar 15 per cent. In test 1 of table 2, powdered whole eggs, powdered sugar or a combination of the two were added to several attractive foods to evaluate their ability to improve foods attractive to the firebrat. The combination of wheat flour 85 per cent, powdered sugar 15 per cent, was found to be significantly (99:1) better than egg noodles or the combination of egg noodles 85 per cent and powdered sugar 15 per cent in this test. Dried whole eggs added at the rate of 5, 10 and 20 per cent to wheat flour were as good as or better than egg noodles. In tests 1 and 4, no combination of foods was found to be more attractive to the firebrat than the flour 85 per cent powdered sugar 15 per cent combination.

It is striking that the four food combinations containing karaya gum were at the bottom of the list in test 3 of table 2. Karaya gum by itself in previous tests appeared to be attractive to firebrats.

In previous tests it has been shown that the firebrat liked egg noodles and macaroni, both of which contain durum flour

which has a higher percentage of gluten than ordinary wheat flour. In test 3, of table 2 wheat gluten, at concentrations of 15 per cent and 30 per cent, was added to ordinary flour in an attempt to improve its attractiveness to firebrats. However, the flour-gluten combination did not prove as attractive as the flour containing 15 per cent powdered sugar.

A number of food combinations have been found to be very attractive to firebrats. Flour 85 per cent, powdered sugar 15 per cent, would appear to be the best and easiest to mix of these food combinations, having the advantages of being readily obtainable, favorably priced, and remaining stable after long periods of exposure to household temperatures. Other

Table 2.—Rating of 24 foods or combinations of foods in attractiveness to the firebrat when wheat flour 85%, powdered sugar 15% is given the arbitrary figure of 100.[1]

Food	Test Number			
	1	2	3	4
Wheat flour 60%, powdered sugar 15%, powdered whole eggs 10%, dried skim milk 15%		351[2,3]		
Wheat flour 70%, powdered whole eggs 30%			276[2,3]	
Macaroni 85%, powdered sugar 15%	119			
Wheat flour 70%, powdered sugar 15%, dried skim milk 15%				118
Wheat flour 70%, powdered sugar 15%, powdered whole eggs 15%				108
Wheat flour 70%, Golden Flow[4] 30%				105
Wheat flour 80%, powdered whole eggs 20%	104			
Wheat flour 85%, powdered sugar 15%	100	100	100	100
Cream of Wheat 90%, powdered sugar, 10%			97	
Wheat flour 55%, powdered sugar 15%, dried skim milk 15%, dried whole eggs 15%				96
Karaya gum 85%, powdered sugar 15%	95			
Sunnyfield ready-mix pancake flour		85		
Wheat flour 80%, dried brewer's yeast 5%, beef meal 15%				85
Cream of Wheat 85%, powdered sugar 15%	83			
Wheat 85%, powdered sugar 15%	81			
Wheat flour 68%, powdered sugar 15%, powdered whole eggs 17%	80			
Cream of Wheat 95%, powdered sugar 5%			76	
Wheat flour 50%, powdered sugar 50%		71		
Karaya gum		71		
Wheat flour 70%, dried skim milk 15%, powdered whole eggs 15%				70
Wheat flour 90%, dried brewer's yeast 10%			66	
Wheat flour 85%, dried skim milk 15%				62
Wheat flour 70%, powdered sugar 15%, wheat gluten 15%				58
Wheat flour 85%, powdered whole eggs 15%				52

[1] Foods found to be significantly inferior to wheat flour 85%, powdered sugar 15% are listed in text.
[2] At the 1% level (99:1) significantly better than all other foods in that test.
[3] At the 1% level (99:1) significantly better than wheat flour 85%, powdered sugar 15%.
[4] Trade name for product containing dried milk and eggs.

Egg albumen, dried skim milk, powdered sugar, and dried whole eggs were evaluated for their use in wheat flour to improve its attractiveness to firebrats in test 4 of table 2.

In these experiments, 138 individual foods or combinations of foods were tested and 53 individual foods or combinations of foods re-evaluated. The most attractive foods or food combinations are listed in tables 1 and 2. The use of dried whole eggs in the food of firebrats is generally not to be recommended because of the price and lack of availability. Dried eggs will also become rancid if allowed to remain for long periods of time at room temperature.

foods as attractive as this combination to firebrats may be found in the tables, and their use would be justifiable if the ingredients were readily available. It is the author's opinion that if the top 13 food combinations in table 2 were in the same test, there would be no significant difference between them.

In addition to the foods listed in table 2, the following foods and combinations of foods were tested but found to be significantly inferior at the 1 per cent level (99:1) to the combination of wheat flour 85 per cent, powdered sugar 15 per cent. In test 1, wheat flour 90 per cent, dried whole eggs 10 per cent; egg noodles 85 per cent, powdered sugar 15 per cent; wheat

flour 90 per cent, powdered sugar 10 per cent; egg noodles; *Sunnyfield* ready-mix pancake flour 85 per cent, powdered sugar 15 per cent; wheat flour 95 per cent, dried whole eggs 5 per cent; in test 2, *Cream of Wheat;* wheat; macaroni; wheat flour; oatmeal 93 per cent, sugar 4.7 per cent, salt 2.3 per cent; barley; oatmeal; whole wheat bread; in test 3, wheat flour 85 per cent, wheat gluten 15 per cent; wheat gluten; wheat flour 70 per cent, wheat gluten 30 per cent; wheat flour 50 per cent, pollen 50 per cent; wheat flour 95 per cent, dried brewer's yeast 5 per cent; wheat flour 75 per cent, beeswax 25 per cent; wheat flour, 85 per cent, *Sunseal* wheat paste 15 per cent; wheat flour 67 per cent, proplis 33 per cent; in test 4, wheat flour 70 per cent, dried skimmed milk 15 per cent, egg albumen 15 per cent; wheat flour 85 per cent, egg albumen 15 per cent; wheat flour 70 per cent, egg albumen 15 per cent, powdered sugar 15 per cent.

Any one of the number of attractive food combinations listed in tables 1 and 2 to which has been added a suitable poison should be readily eaten by the firebrat and therefore useful for their control.

SUMMARY.—1. A method was developed so that the attractiveness of foods to the firebrat, could be evaluated.

2. The firebrat is capable of selection among foods equally available.

3. Different foods or combinations, totaling 138 in number, were evaluated for the firebrat. Fifty-three of these were re-evaluated.

4. A number of foods or food combinations have been found attractive to the firebrat. Because of ease of mixing and availability, wheat flour 85 per cent, powdered sugar 15 per cent appears to be the food combination most practical for use in baits for this insect.

5. Sugar, when added to some baits, improved their attractiveness.

6. Salt did not improve the attractiveness of flour.

7. A combination of certain baits proved more attractive than any of the component parts.—6-30-45.

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STATE QUARANTINES REVISED

Revisions of State quarantines pertaining to the Oriental fruit moth.—The quarantine of Arizona, pertaining to the Oriental fruit moth, was revised June 20, 1945; that of Oregon, June 15, 1945; and of Washington, June 28, 1945. These revisions reduced the quarantined area in the State of Idaho to Canyon and Owyhee Counties. The revisions of Arizona and Washington added also Merced County, California; and that of Oregon, the county of Jefferson, Colorado, to the quarantined area.

Revision in California sweetpotato weevil quarantine.—An amendment of the sweetpotato weevil quarantine of California was issued May 8, 1945 which removed from the infested areas Butler County, Alabama; 17 counties in northwest Florida; Thomas County, Georgia; the Parish of West Feliciana, Louisiana; Stone County, Mississippi, and the entire State of Kentucky, and added to the infested areas all of Glynn County, Georgia; the Parishes of De Soto and Sabine, Louisiana; Greene County, Mississippi, and Mills and Shelby Counties, Texas.

Revision of State quarantines on account of the European corn borer.—State quarantines on account of the European corn borer were revised July 1, 1945 by Tennessee; June 14, 1945 by Oregon; and June 28, 1945 by Washington. These revisions brought under regulation for the first time the entire states of Kansas and Nebraska. The revisions of Oregon and Washington also brought under regulation for the first time the counties of Montgomery Robertson, and Sumner in Tennessee. That part of Minnesota not previously included was brought under regulation by the State of Tennessee and the entire state of Minnesota by Washington. Those parts of Iowa and Missouri not previously under quarantine were added by the states of Oregon and Washington.

Texas Pink Bollworm Quarantine Revised.—The pink bollworm quarantine and regulations (Quarantine Proclamation No. 67) of Texas were revised effective July 5, 1945 to add to the lightly infested regulated area 21 entire counties and parts of four others which were previously not completely under regulation. The revision also added to the heavily infested area the counties of Cameron, Hidalgo, Hudspeth, Starr, Willacy, and that part of El Paso County which was formerly designated as lighly infested. Additional restrictions were imposed on movement of cotton seed from heavily infested regulated areas and the requirements on production of okra in lightly infested regulated areas were modified. An amendment of August 10, 1945 removed all quarantine restrictions from the County of Hockley and the quarantine portion of Lamb County until further notice.

Further Observations on Host Plants of the Pink Bollworm in the Lower Rio Grande Valley of Texas and Mexico

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Observations on secondary host plants of the pink bollworm of cotton, *Pectinophora gossypiella* (Saund.), in the lower Rio Grande Valley of Texas and in the adjacent area of Matamoros, Tamaulipas, Mexico, were continued through 1943–44.

As reported by Bibby and Moreno (1941) and by Fife and Moreno (1943), five malvaceous plants other than cotton have been found serving as hosts of the pink bollworm, namely, *Abutilon trisculcatum* (Jacq.) Urban, *Hibiscus esculentus* L., *H. syriacus* L., *Malvaviscus drummondii* Torr. & Gray, and *Pseudabutilon lozani* (Rose) Fries. Further observations on some of these mallows and on three others, *Hibiscus cardiophyllus* Gray, *H. mutabilis* L., and *Malvaviscus arboreous* Cav., are discussed in this paper.

A heavier infestation of pink bollworm in *Hibiscus esculentus* than had been found previously was discovered in a field of okra near Matamoros on November 13, 1943. This field was about 3 miles from the nearest cotton. Examination of 100 dry and 100 green seed pods collected at random from the field revealed that all of the dry pods and 51 of the green ones were infested. The dry okra pods yielded 294 mature pink bollworms, most of which were in the resting stage, and the green pods yielded 79 pink bollworm larvae, most of them mature.

A total of 47,865 fruiting forms of the wild mallow *Malvaviscus drummondii*, collected during the fall of 1942, were placed in indoor cages and held for moth emergence, as reported by Fife and Moreno (1943). Upon examination of this material in January 1943, 9 pink bollworms in the resting stage were found, 2 being in seed pods and 7 in blooms. During the fall of 1943 a total of 6950 fruiting forms of *M. drummondii* were also installed in screen cages indoors for emergence of moths. From this material 72 pink bollworm moths emerged between October 29 and November 13. This material was transferred to outdoor cages in January 1944, to be observed under less artificial conditions. A total of 10 moths emerged in these cages between February 21 and March 11, 1944, the last emergence being 5 months after the date of collection. The presence of resting-stage larvae and the emergence of moths in February and March indicated that *M. drummondii* might serve as a source of infestation to cotton.

During the fall of 1943, 52,100 green and dry seed pods of *Pseudabutilon lozani* were collected in Texas and Mexico and installed in outdoor hibernation cages equipped with pyramid covers and with traps for collecting the emerging moths. Since the seed pods of this mallow tend to hang onto the plants for a considerable period after ripening, they were placed on screen-wire trays above the ground in the cages, to simulate natural conditions and thus aid in determining whether the pink bollworms could overwinter in this mallow. The entire lot of pods was thoroughly mixed, and a sample consisting of 1000 pods was examined in order to estimate the number of worms present. Twelve pink bollworm larvae, 9 mature and 3 immature, were found. On this basis it was estimated that approximately 625 larvae had been installed in the hibernation cages.

A total of 125 pink bollworm moths emerged from the pods in the cages between December 6, 1943, and June 10, 1944, as follows: 11 in December, 55 in January, 35 in February, 12 in March, 10 in April, 1 in May, and 1 in June. This definitely indicates that the pink bollworm might overwinter under natural conditions in the resting stage in seed pods of *Pseudabutilon lozani* and be a source of infestation for the next cotton crop. In 1944, 4 pink bollworm larvae were found, 1 in January and 3 in March, by examining 295 seed pods of *P. lozani* collected in its natural habitat. In another test cotton squares were infested with pink bollworms hatched from eggs laid by moths that emerged from cages containing dry pods

[1] All members of the Brownsville, Tex., laboratory assisted in the investigations reported in this paper.

[2] In cooperation with the Delegacion Fitosanitaria in Matamoros, Tamaulipas, Mexico, and the Texas Agricultural Experiment Station.

of *P. lozani*. This test definitely showed that the pink bollworms developing on *P. lozani* can transfer to cotton.

One mature pink bollworm larva was found during the examination of approximately 186 green and dry seed pods of *Hibiscus cardiophyllus* collected at Barreda, Tex., in October 1943. Although this plant is a well-known host of the pink bollworm, it constituted a new record for the lower Rio Grande Valley. *H. cardiophyllus* is a perennial found in several counties in Texas, and also in the adjacent Matameros and Reynosa areas of Mexico, from near the mouth of the Rio Grande to a distance of 125 miles west on the Texas side and 90 miles on the Mexican side. Although this species is present in locations where the topography is slightly rolling and the soil fertile, it apparently prefers a well-drained soil and is often found on hilltops and hillsides, where soil is scarce. Under favorable conditions *H. cardiophyllus* fruits throughout the year, but more abundantly in the spring and fall.

In a sample of 425 fruiting forms of the well-known ornamental mallow *Hibiscus mutabilis*—known also as cottonrose, confederate rose, and friendship-of-a-day—collected at Brownsville, Tex., in November 1943, 6 pink bollworm larvae were found. This mallow was thereby established as another secondary host plant of the pink bollworm in this area. This shrub grows from 8 to 10 feet high and bears many buds, blooms, and seed pods. The young plants closely resemble cotton *H. mutabilis* is not abundant in this area, but is often found in gardens and backyards.

The ornamental mallow *Malvaviscus arborous*, known as the cultivated turkscap, was recently found to be a secondary host of the pink bollworm. A total of 10 mature and immature pink bollworms were found during the examination of about 100 blooms collected in Brownsville on October 3 and 11, 1944. In another sample containing approximately 1,525 flower buds and blooms, collected near Matamoros on October 30, 2 mature pink bollworms were found, making a total of 12 larvae found on this plant. This is a new host record for the pink bollworm. *M. arboreus* is one of the commonest of all cultivated mallows in this area. The plant grows from 5 to 15 feet high and bears many partly closed, bag-shaped red blooms 3 inches long, but it never produces seed pods. In this area, under favorable conditions, *M. arboreus* produces flowers throughout the year. Although this plant occurs in most sections of the lower Rio Grande Valley, infested blooms were found only on plants growing adjacent to heavily infested cotton.

Many negative results from examinations made of the mallows discussed and of other potential wild and cultivated hosts of the pink bollworm were obtained, but are not reported.

The pink bollworm infestation in secondary host plants depends upon the intensity of infestation in cotton, the proximity of these plants to cotton fields, and the time of year when the secondary host plants fruit. The most favorable period for infestation of secondary hosts is the fall of the year, when infestation in cotton is heaviest and cotton stalks are destroyed in the fields. The importance of these secondary hosts in maintaining the pink bollworm infestation in the lower Rio Grande Valley of Texas and Mexico has not been established.—6-19-45.

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Fife, L. C., and I. Moreno. 1943. Additional notes on host plants of the pink bollworm in Texas and Mexico. JOUR. ECON. ENT. 36(3): 478–9.

Quarantine No. 7, pertaining to the Oriental fruit moth in California, was revoked July 17, 1945 and Quarantine No. 3 of California, pertaining to the Oriental fruit moth in other States, was revoked July 20, 1945.

The intrastate quarantine of Missouri on account of *Parlatoria chinensis*, a scale insect, was revoked August 3, 1945.

Biology and Control of Ash Plant Bugs in California

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Ash trees are grown extensively throughout the United States for shade and for ornamental purposes. Because of their rapid growth and resistance to drought they are particularly suitable for the many miles of highways which they line in the central valleys of California. It is unfortunate that such an adaptable tree is subject to attack by several omnipresent native insect pests. Most important insect enemies in California are plant bugs of the genus *Neoborus*, aphids of the genus *Prociphilus*, and the ash lace bug, *Leptoypha minor* McAtee. The aphids curl the leaves badly and secrete great quantities of honey-dew in the early spring. They disappear with the onset of dry weather and are said to migrate to alternate hosts during the summer (Essig 1926). The ash lace bug overwinters as an adult and builds up in population until late summer when it may defoliate the trees. This pest will be treated in a later paper.

The ash plant bugs belong to three closely related genera of Miridae, *Neoborus* Distant, *Xenoborus* Reuter, and *Tropidosteptes* Uhler. Their closest relatives are the tarnished plant bugs (genus *Lygus*). Forty-three different ash plant bugs have been described from North and Central America. Of the 20 species for which host records are available, 15 occur on various species of *Fraxinus*, and one each on a species of *Crataegus* (Knight 1929); Swamp privet, *Adelia parvifolia* (Knight 1929); Cottonwood (Knight 1929); Fringe tree, *Chionanthus virginica* (Knight 1927); and a mistletoe, *Phoradendron villosum*, on oaks (Van Duzee 1921).

By far the commonest and most widespread species in California is *Neoborus illitus* Van Duzee (1921). It is the principal cause of damage to the Arizona ash, *Fraxinus velutina* Torrey, in the parks and along the highways and has been reported as injurious in Tehama, Glenn, Colusa, Yuba, Sonoma, Napa, Yolo, Sacramento, Solano, Marin, San Joaquin, Stanislaus, Merced, Tulare, and Los Angeles counties. Another common species, *Neoborus pacificus* Van Duzee (1921) was described from Corvallis, Oregon. I have found it commonly on Oregon ash in Tuolumne County, California and on Arizona ash in Yolo County, California. Nymphs of *pacificus* are green with black spots rather than brown as in *illitus* and adults are uniform light brown rather than black or brown and yellow as in *illitus*.

According to Dickerson & Weiss (1916), the eastern "ash leaf bug," *Neoborus amoenus* Reuter (1909) passes through two generations a year and the eggs are "deposited in the midribs on the undersides of young, tender leaves." They further state that "the whitish circular rim of the egg cap projects out a slight distance." It is not stated where or in what stage the insect passes the winter.

In California *Neoborus illitus* produces but a single generation each year. The eggs hatch late in February or early in March. Nymphal development takes place during March and part of April and the oviposition period is completed by the middle of May at Davis. The last bugs disappear during June, not to be seen again until the following spring. *Neoborus illitus* eggs in California are deeply embedded in the stems and thus remain on the trees throughout the dry summer and fall and through the dormant winter season. *Neoborus pacificus* is similar to *N. illitus* except that it lays its eggs in the petioles or along the midribs of the leaves as well as in the woody tissue. At least one more generation appears before *pacificus* dies out in July. The following detailed life history notes and descriptions refer to *Neoborus illitus*.

EGGS.—Gravid females dissected during April and May were found to contain from 8 to 10 fully formed eggs. Males became scarce late in April and were all gone by the middle of May at Davis. Eggs are laid in stems of new growth of the current season. Punctures are first made by probing with the stylets after which the ovipositor is inserted. The eggs are usually embedded so that only the narrow, whitish, convex cap is visible at the surface (Fig. 1 A). Scars are formed in the stems around a mass of eggs, the scars appearing as elongate or irregular slits one-fourth to one-half inch across. As many as twenty-four eggs were found

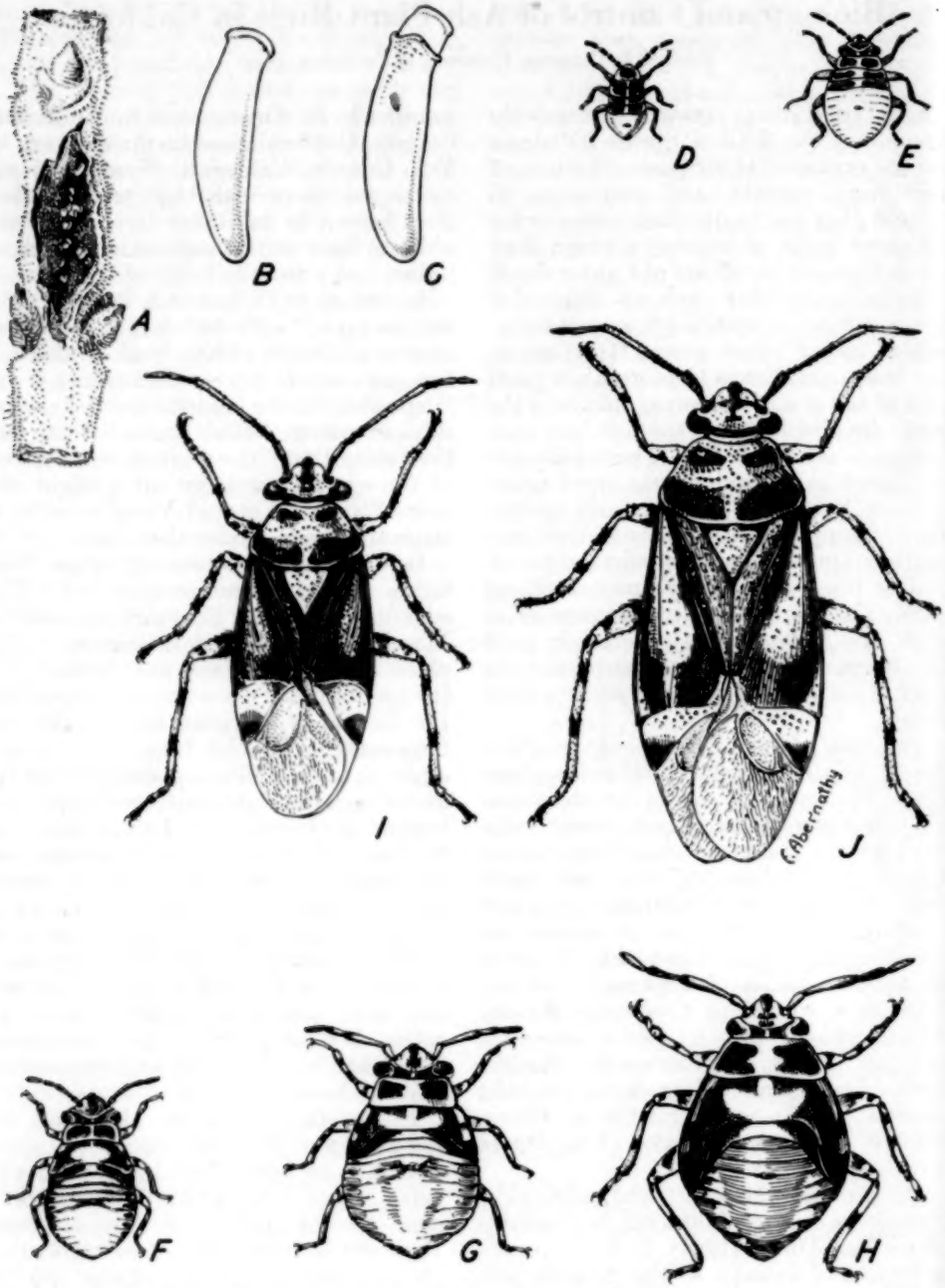

FIG. 1.—Life history of *Neoborus illitus* Van D. A, Egg scar on stem showing egg caps *in situ*. B, Recently laid egg dissected from stem tissue. C, Fully developed egg dissected from stem tissue showing extruded yolk plug. D–H, Successive nymphal instars from first to fifth. I, Adult male. J, Adult female.

packed into a single quarter-inch area of this sort. The surface scar tissue and often the terminal portion of the shoot are dead but the tissue beneath the egg puncture scars is still quite fresh. The egg caps are white, narrow, obliquely convex and roughened. Although soft and somewhat formless when recently laid, eggs dissected from plant tissue were clear, water yellow in color, elongate in form,

and slightly curved at the anterior end. They averaged .9 mm. in length, .275 mm. in width slightly behind the middle and .225 mm. across the micropylar cap (Fig. 1 B). No reddish eye spots were seen during the summer and fall, indicating that embryonic development was not far advanced.

Eggs in an advanced stage of development were examined on February 25, 1941. At this time the shoots containing egg scars were dead, at least at the tips, the eggs thus appearing to be embedded in dead corky tissue. This is less remarkable than the deliberate oviposition by some mirids in fence posts and other dead wood (Steer 1929). The eggs were partially exposed and showed distinct red eye spots. The micropylar cap had split open in each case and a cylindrical plug of yolk covered by a thin membrane had been extruded. The swelling of the egg by absorption of moisture and the extrusion of the subopercular yolk plug has been described for another mirid, *Notostira erratica* (Linn.) by Johnson (1934). Dissection of *Neoborus* eggs from the plant tissue was difficult at this time because slight pressure on the sides of the egg forced the yolk plug off, due to pressure from below by the embryo. The length at this time, including extruded yolk plug, averaged 1.006 mm., the length of the plug beyond apex of egg, .2 mm.; and the greatest diameter of the egg, .28 mm. (Fig. 1 C).

ECLOSION.—Hatching took place at Davis in the spring of 1941 between February 27 and March 11. This coincided perfectly with the appearance of the first leaves of the ash trees. Stems with eggs about to hatch were placed in cellophane cages on uninfested ash trees. After 24 hours of hatching the eggs were removed and the nymphs of known age were followed through to adults in these cages.

NYMPHAL DEVELOPMENT.—Nymphs increased in size and passed through five instars in about twenty-five days. The average length of instars one to five under field conditions was 4, 4, 4, 5, 8. The successive instars increased in length as follows: .7, 1.12, 1.65, 2.15, 2.5 mm.; and in head width (across eyes) as follows: .25, .43, .63, .75, .93 mm.

FIFTH NYMPHAL INSTAR (Fig. 1 H).—Oval in outline, convex above, generally brown in color with white and reddish markings, the surface glabrous and highly polished. Head strongly declivous, half again as broad across eyes as long, the tylus moderately and juga and lora strongly swollen. Inner margins of eyes strongly anteriorly divergent. Antennae inserted in short, socket-like tubercles. Antennae a little less than twice as long as width of head across eyes, 64::37; proportion of segments one to four as 11:28:14:11; first segment slender basally, second and third nearly cylindrical, fourth spindle-like. Rostrum reaching posterior coxae, proportion of segments one to four as 10:10:7:10; first segment strongly expanded apically, especially ventrally, second narrow, third distinctly broadened at middle, fourth narrower, acuminate apically. Labrum about half as long as first rostral segment, swollen, tapering towards apex.

Pronotum three-fourths as long as head and one-sixth broader than head, the front margin slightly concave, side margins subrectilinear, strongly divergent posteriorly, hind margin convex, angles rounded. Mesonotum almost one-fourth longer than pronotum on median line, 22::18, the sides broadly dilated and rounded forming outer margins of hemelytral pads, the body as wide across wing pads as length of antennae, the pads reaching sixth abdominal segment, hind margin of mesonotum between hemelytral pads feebly angulately produced at middle. Metanotum less than one-fourth as long as mesonotum at middle, feebly angulately emarginate between the wing pads, the inner portions of wing pads broadly exposed except toward apices where the hemelytral pads completely cover them. Pale portions of pronotal and mesonotal disks with numerous superficial punctures visible.

Abdomen with the segments subequal in length at middle, the sutures relatively straight except posteriorly, nymphal scent gland opening small, transverse, located at middle of suture between third and fourth abdominal segments. Ninth and tenth segments narrowed, broadly connate. Under surface appearing concave due to the strongly overlapping hemelytral pads. Tarsi two-segmented, the basal segment very short.

Color largely brownish above, the head with white juga, white margins of eyes, and ochraceous frons except for brown vitta extending backward from tylus and

broad brown areas above insertions of antennae; pronotum with white margins and a pale area at middle; mesonotum pale along mid-line and broadly on posterior two-thirds of middle region between hemelytral pads, the pale area extending further forward on either side. Hemelytral pads obscurely pale along extreme

FIG. 2.—Injury to stems and leaves of current season's growth.

lateral margins and with an obscure pale vitta sublaterally, broadest at base and extending as a narrow fascia for about half the length of pad, with a round sublateral spot at about apical fourth. Metanotum pale along middle and irregularly along hind margin between wing pads. Abdomen reddish above with pale at middle of first segment and sublaterally on posterior half with brown at scent gland opening and on ninth and tenth segments. Antennae pale with lightly infuscated base and apex of second segment, third segment, and base of fourth. Rostrum pale with black labrum and black apex. Legs pale, the femora with broad median and small subapical brown spots, tibiae brown at base, broadly a little beyond base and narrowly at middle, tarsi dark brown to black. Under surface pale medially and reddish laterally, the abdomen reddish with pale irregularly on median convex area and surrounding spiracles with a connection to pale margins.

ADULTS.—(Fig. 1, I and J).—The adults have been described by Van Duzee (1921). They are strikingly sexually dimorphic.

TYPE OF INJURY.—Initial injury is caused by the recently hatched first instar nymphs which concentrate on the opening buds. The new leaves are the only source of nourishment for the young bugs. As development proceeds the larger nymphs feed upon the new growth. White areas and black excrement spots on the leaves are typical of this stage with eventual browning and curling of the leaves. Meanwhile stem feeding produces a condition of general wilt at the ends of branches and finally a curling and drying of all new growth (Fig. 2).

Continued feeding by later nymphal instars and by adults on stems, leaves, seeds and male flowers causes partial or complete defoliation. During May entire trees in the vicinity of Davis are defoliated. The branches are completely devoid of leaves, only dead sprigs remaining as evidence of the season's growth. This is the climax of injury for the season. With the bugs gone and next season's eggs deeply embedded in the stems, the tree puts out new foliage. By July a superficially normal appearance has been achieved (Fig. 3). Only inspection of individual branches reveals the dead twigs of the earlier growing period (Fig. 4).

CONTROL.—Because of the type of life history and feeding habits, two methods of control were indicated: dormant ovicides during the winter months and contact sprays in the spring for nymphs and

FIG. 3.—Left. Defoliated ash tree compared with an adjacent relatively uninfested tree, Davis, May, 1940. Right. The same tree after completion of oviposition and death of the bugs, Davis, August, 1940.

adults. One ovicide used was the triethanolamine salt of 2,4 dinitro-ortho-6-cyclo-hexyl-phenol[1] at 1 to 400 with 2 per

[1] A product of the Dow Chemical Co., Midland, Michigan.

cent *Winter Toxoluble Oil* of 82 viscosity and 76 U. R. *Vatsol*[1] was added at 1 to 1600 as a wetting agent. This mixture has been abbreviated "DNOP" in table 1. The other ovicide used was 3,5 dinitro-ortho-cresol (abbreviated "DNOC")[2] at 1 per cent strength. Other insecticides used were lauryl thiocyanate;[3] an oil emulsion containing 75 per cent by volume of petroleum oils and 25 per cent inert ingredients with 92 per cent U. R.[4] (abbreviated "oil emulsion") combined with nicotine sulfate;[5] beta-butoxy-beta-thiocyano-diethyl-ether[6] (abbreviated "butoxy thiocyanate"); and a western olefene base oil containing 30 per cent oleic acid and a spreader (abbreviated "oil-oleic acid") to which is added 20 per cent of a derris extract in camphor sassafras base oil containing 5 grams of rotenone in 100 cc.[7] (abbreviated "rotenone C. S."). To this rotenone-oil mixture was added a nicotine alkaloid and pyrethrum containing not less than 2.5 per cent pyrethrins[8] (abbreviated "pyrethrum").

Results are summarized in table 1, the January and February applications being dormant strength ovicides, the March sprays being directed at the nymphs and the April applications at the adults. Good coverage was obtained with 10 gallons of spray when the trees were dormant while 20 gallons were necessary after the foliage appeared.

The "per cent kill" was determined for the ovicides by dissecting one hundred eggs from the stems of a tree one week after spraying. Death was determined by the shriveled condition of the embryo. All eggs were alive in the control whereas the percentages indicated in table 1 were dead in the sprayed samples. Each figure of "per cent kill" is an average of three samples of 100 eggs each.

FIG. 4.—Left. Defoliated branch, May, 1940. Right. Defoliated branch with new summer foliage.

"Per cent kill" for nymphs and adults was determined by counting 100 insects 24 hours after spraying and noting the number of dead bugs as compared with live bugs. The dead bugs were shriveled and motionless and hence easily recognized amidst the foliage. The control consisted entirely of live bugs in each case. Figures of "per cent kill" are an average of three counts of 100 bugs each from different parts of a single sprayed tree.

Several facts are evident from the table. First, an oil ovicide shows promise if used at sufficient strength and has the added advantage that coverage is easy and requires relatively less volume of spray.

[1] A product of the Am. Cyanamid and Chem. Corp., N. Y.
[2] *Elgetol*, a product of Standard Agricultural Chemicals, Inc., Hoboken, N. J.
[3] *Lethane Junior*, a product of Rohm & Haas, Philadelphia, Pa.
[4] *Arboral*, a product of California Spray-Chemical Corp., Richmond, Calif.
[5] *Black Leaf 40*, a product of Tobacco By-Products and Chemical Corp., Louisville, Ky.
[6] *Loro*, a product of E. I. du Pont de Nemours and Co., Wilmington, Del.
[7] *Stantex Dispersing Oil-R-50*, a product of Standard Agricultural Chemicals, Inc., Hoboken, N. J.
[8] *Pyrocide 20*, Deodorized and Clarified Liquid Insecticide, a product of McLaughlin Gormley King Co., Minneapolis, Minn.

Second, a wide variety of sprays were at least moderately effective on the nymphs and on the adults. Third, the most effective spray was rotenone or pyrethrum combined with a mineral oil containing a small percentage of oleic acid and a spreader. The rotenone-oil mixture at a dilution of 1 to 400 gave complete control of both nymphs and adults.

Contact sprays should be applied after complete hatching of eggs, about March 15 at Davis in 1941. Thorough coverage at this time not only prevents further injury for the year but precludes injury for the following year because no eggs are laid to carry over and start a new generation. In compound infestations involving two or more species, a later application in May or June is indicated.

Table 1.—Summary of experiments on the control of the ash plant bug.

Insecticide	Oil	Wetter or Spreader	Date of Application	Per Cent Kill
DNOP 1–400	*Winter Toxoluble* 2 per cent	*Vatsol* 1–1600	1-30-41	92
DNOC 1 per cent			2-27-41	24
Lauryl thiocyanate 1–400		*Mouillant* 1–125	3-19-41	94
Nicotine sulfate 1–1200	*Arborol* 1–50		3-19-41	95
Butoxy thiocyanate 1–1000		*Grasselli* 1–400	3-19-41	96
Rotenone C. S. 1–800	oil-oleic acid 1–800	blood albumin 1–3200	3-20-41	81
Rotenone C. S. 1–400	oil-oleic acid 1–400	blood albumin 1–3200	3-20-41	100
Rotenone C. S. 1–200	oil-oleic acid 1–200	blood albumin 1–3200	3-20-41	98
Nicotine alkaloid 1–2400	oil-oleic acid 1–400		3-20-41	92
Pyrethrum 1–1200	oil-oleic acid 1–400	blood albumin 1–3200	3-20-41	100
Rotenone C. S. 1–400	oil-oleic acid 1–400	blood albumin 1–3200	4-14-41	100
Rotenone C. S. 1–200	oil-oleic acid 1–200	blood albumin 1–3200	4-14-41	100

Summary.—The ash plant bug, *Neoborus illitus* Van D., is at present the worst pest of ornamental ash trees in California. It is univoltine. The eggs hatch when the first leaves appear late in February and early in March in the vicinity of Davis. Nymphal development requires approximately 25 days, the insect passing through five nymphal instars. Mating takes place about the middle of April and the males die off soon after this. The females oviposit in the stems of the current year's growth during April and May. The eggs remain embedded in the plant tissue in a relatively undeveloped condition during the summer and fall. They develop more rapidly and swell by absorption of water during the winter. Expansion is possible only in one direction so the egg cap bursts and a yolk plug is extruded. Hatching follows and the annual cycle is repeated. *Neoborus pacificus* is less abundant on ornamental trees. It undergoes a life cycle similar to *illitus* except for the second spring generation.

Injury starts with the feeding of newly emerged nymphs on the opening buds. White areas devoid of chlorophyll and black excrement spots are characteristic evidence on large leaves while the stems and entire current season's growth wilt as the season advances. Finally entire limbs become defoliated. After oviposition and death of the bugs, new leaves are put forth and the tree regains a superficially normal appearance during the summer months.

Control with the triethanolamine salt of 2,4-dinitro-ortho-6-cyclo-hexyl-phenol at 1 to 400 with 2 per cent *Winter Toxoluble Oil* and *Vatsol* as a wetting agent at 1 to 1600 was effective (92 per cent kill) as an ovicide. A mineral oil with oleic acid,

a spreader, and rotenone in camphor sassafras oil gave complete control of both nymphs and adults at dilutions of 1 to 400 with blood albumin as a spreader. The oil-rotenone spray should be applied during March and April because at this time the bugs are wingless and hence are unable to fly away and avoid the spray. Moreover, control at this time prevents oviposition, thus precluding development of the next year's generation.[1]—6-19-45.

[1] Valuable assistance with spray equipment was rendered by J. D. Matley and W. A. Westgate of the Standard Agricultural Chemical Co., and personnel of the Dow Chemical Co., and G. F. MacLeod, W. M. Hoskins, and S. F. Bailey of the University of California offered suggestions in connection with control methods and materials.

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Insect Pathology and Biological Control[1]

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To most entomologists the term biological control first suggests to their minds the use of certain insects which parasitize and usually destroy other insects. Such a conception is only natural since most of the emphasis and experimental work in biological control has been concerned with parasitic insects. In the time allotted for this talk, however, I should like to emphasize a few general aspects of another important type of biological control, namely, that brought about by the natural and artificial use of parasitic and disease-producing microorganisms including bacteria, fungi, protozoa, and viruses.

In recent years, anyone who has attempted to speak on the role of microorganisms in the control of insects has usually had to do so before an audience somewhat prejudiced against his subject, or at least very skeptical of the worthwhileness of it all. In light of past experiences, perhaps this "show me" attitude is only natural and, in fact, warranted. On the other hand, if for no other reason than for the sake of the realization of the full scope of the field of biological control, we ought to assume a more open-minded viewpoint, realizing that the last word on this subject has by no means been spoken. In fact, the practical and full realizations of the field appear to lie largely in the future and it is encouraging to hear men like Professor E. O. Essig, say, as he did in his recent presidential address to the American Association of Economic Entomologists: "This field of investigation [*i.e.*, biological control] is still capable of great expansion and we can hardly visualize the heights that may be attained by the expert use of bacteria, fungi, and insects in this connection."

We must admit, however, that except in a few cases, extensive use of microorganisms in the control of insects has so far not worked out too well. Therefore, it is pertinent that we ask: "To what may this over-all apparent lack of success be attributed?"

In the first place, the field of insect microbiology or insect pathology has been a neglected one. There are several reasons for this, one of which is the fact that it is a borderline field between entomology and microbiology, the latter including the sciences of bacteriology, mycology, protozoology, virology, and immunology. It is a rare entomologist who has taken extensive or adequate training in the microbiological sciences, and similarly, the microbiologist has seldom troubled himself to take proper training in entomology. Because of this state of affairs, specialists have not been prone to delve into the borderline field of insect diseases and as a result the applications to biological control have been carried on largely in a dilettante spirit.

[1] Presented before the Entomological Club of Southern California, at Alhambra, June 1, 1945.

In the second place, initial reports concerning the efficacy of such forms of biological control were frequently over-enthusiastic and, after a few disappointing failures, the early optimism was replaced by undue pessimism. This gave rise to unjustified criticism regarding all phases of insect control through the use of microorganisms and a general lack of interest in the field.

Perhaps the greatest single reason for the present skepticism and lack of success in this branch of biological control is the need of adequate information and understanding concerning the essential factors underlying the general use of microbes against insects in nature. The factors of "biotic potential" (reproductive potential and survival potential), and "environmental resistance," well-known with respect to entomophagous insects, have hardly been considered in relation to the diseases of insects. All too frequently it is forgotten that parasitic microorganisms are an important part of the environmental resistance which opposes the biotic potential of any given insect. As is so often the case with things which promise to hold great practical benefits we have gone pell-mell ahead attempting to use microorganisms without stopping to do much of the fundamental research necessary for an adequate understanding of the various biological relationships which exist between microorganisms and insects. We have very little information as to the factors and potentialities concerned in the artificial use of microorganisms in controlling insects or even as to how we can assist nature in bringing about the disease outbreaks of her own accord.

I should like to point out some of the blind spots in our knowledge of insect diseases by asking the following questions:

(1) Just how great a factor are diseases in the *natural* control of insects? Can anyone offer more than mere guesses or estimates on this point?
(2) How great a factor are, or how great a factor can diseases be in the *artificial* control of insects? What do we know of the biological relationships involved in such applications?
(3) How can the saturation points of the microorganisms in a given set-up be determined or controlled and how can the saturation point for any particular microorganism and insect be brought about?
(4) Of what importance are diseases occurring in insects which have been weakened by other means of control (chemical, environmental, and biological)?
(5) What part of so-called "natural mortality" or "unexplained mortality" is due to disease?
(6) Under certain conditions do the symbiotes normally associated with insects assume the role of pathogens and cause the death of their hosts?
(7) Is there any way of predicting the outbreak of epizootics? Such information would certainly be of great value to the agriculturist.
(8) What are the best means of preventing and controlling disease in our insectaries?
(9) Should we not know more about the diseases of our beneficial insects in general?
(10) Does microbial disease ever prevent the full realization of the success of introduced insect parasites?
(11) Cannot some system be devised whereby statistical data on disease outbreaks would be collected, analyzed, and be put to practical use?

Of course, there are many other queries as pertinent as these which could be asked but those just mentioned are some of the broad questions which need solution and which the field of insect pathology should strive to answer. It might be well, therefore, to consider in slightly more detail the present status of our answers to one or two of these questions and to point out a few of the possible opportunities for the realization of practical results in the biological control of insects through the medium of disease.

First, let us consider the importance of disease in the *natural* control of insects. Nearly every experienced field entomologist has at one time or another observed disease epidemics or epizootics occurring among insects in nature. Especially has this been seen at times when the insects were present in very large numbers and were greatly crowded together. Unfortunately, most of these epizootics have not been recorded in the literature nor reported to any central agency or laboratory. Still less frequently has anyone taken the time to investigate these outbreaks to determine their cause, extent, or possible practical use.

Numerous examples of these natural epizootics might be cited but I should like especially to refer to two or three which have been observed here in California and in other western states during the past year or two. In northern California and in Oregon and Washington several lepidopterous defoliators are from time to time found heavily diseased in the larval stage. Mr. R. L. Furniss of the Forest Insect Laboratory in Oregon has written me that in 1944 he saw a con-

siderable number of diseased specimens of the black-headed budworm, *Acleris variana*, in the state of Washington. Also in 1944, the western hemlock looper, *Ellopia fiscellaria lugubrosa*, was found heavily diseased in Oregon. This insect has also been found diseased in northern California. Dr. A. E. Michelbacher and Ray F. Smith on several occasions have seen infestations of the alfalfa butterfly, *Colias eurytheme*, almost entirely wiped out in localized areas by disease. In none of these cases has the etiologic agent of the disease been determined.[1]

It would seem that those entomologists interested in the ecology and bionomics of insects can ill afford to ignore the effect of disease on insect populations and the conditions which bring about the outbreak of disease in nature. There are many forces which reduce the biotic potential of or increase the environmental resistance against any given insect. The principal factor in this regard, of course, is climate. Authorities are generally agreed, however, that although climatic factors may destroy the greater percentage of insects, actual control to a state of biological equilibrium is the result of biological rather than physical agencies. The question we are as yet unable to answer in this regard is: Just what part of these biological agencies is assumed by naturally occurring diseases?

Now, for a moment, let us turn to the importance of disease in the *artificial* control of insects. I have already mentioned that due to the past failures of inadequate attempts to aid the control of insect pests by the use of disease organisms, it has been generally concluded by many, that such methods of control are of no practical value whatever. Is this viewpoint justified? True, there have been several instances in which microorganisms were enthusiastically hailed as the ideal control measures only to have the project ultimately deflated by failure. Consider, for example, the acclaim afforded the initial success of the use of the bacterium *Coccobacillus acridiorum* in the control of locusts, or the use of the fungus *Beauveria globulifera* against the chinch bug, or the use of certain protozoa and bacteria in the control of the European corn borer. These have now lost favor in the hands of economic entomologists. Why? Was their advocacy a mere illusion, or perhaps an attempt to save someone's reputation? Is their use entirely without practical value?

Let us consider the disappointing case of *Coccobacillus acridiorum*. This bacterium was first isolated by d'Herelle in Yucatan, Mexico, from the locust *Schistocerca pallens*. While in Mexico, d'Herelle noticed a heavy mortality occurring in the migratory locusts which had arrived from Guatemala. In 1910 and 1911 the epizootic occurred so extensively that by 1912 the numbers of locusts were reduced to the extent that no invasion into Mexico occurred. D'Herelle apparently was also successful in combating plagues of *Schistocerca* in Argentina and Tunisia although in the latter country mechanical methods were also employed. Since d'Herelle's early successes, some workers have been able to confirm his results while others have failed completely. The latter appear to have been in the majority and their pessimism apparently has killed all interest in further consideration of the organism as a means of biological control. Now, just why has this state of affairs come about? Why will success reward one worker while failure results when another attempts to use the same methods? I do not pretend to know the answers and probably some of d'Herelle's claims are unfounded, but I feel that a close inspection of the situation reveals several pertinent and highly significant facts which have been overlooked by many of the critics. For one thing, there seems to be a difference in the susceptibility of different locusts to the disease. The bacteria appear to be more effective against locusts of the genus *Schistocerca* than against other general of the Locustidae. Yet, the method has been condemned by workers using entirely different species of grasshoppers. Secondly, it has been found that several strains of *Coccobacillus acridiorum* exist, not all of which are equally pathogenic. Indeed, Glaser has found that some of the cultures circulating under the name "*Coccobacillus acridiorum*" were not of this species or even genus! Then too, the typical strain of *Coccobacillus acridiorum* rapidly loses its virulence on artificial culture media unless periodically passed through locusts. Furthermore, strains of low virulence and strains of closely re-

[1] Since this was written the author has had the opportunity of examining diseased specimens of *Ellopia fiscelleria lugubrosa* and of *Colias eurytheme*. The infections proved to be polyhedral virus diseases.

lated bacteria are occasionally found normally present in locusts, and these may immunize the insects against the fully virulent *Coccobacillus acridiorum*. Is it any wonder then, that there were a large number of failures reported? When ordinary principles of bacteriology are completely ignored, how can such a method of biological control be said to have had a fair trial? The example just given shows clearly the need for more basic research into the biological relationships involved.

This sort of situation has prevailed throughout the many attempts to use microorganisms to control insects. Dr. H. S. Fawcett has recently pointed out that the lack of the proper understanding of the saturation point may explain why no increased mortality of the chinch bug occurred in areas where spores of the fungus *Beauveria globulifera* were distributed. In other cases it would appear that failure has resulted because advantage was not taken of the fact that the natural distribution of many fungi frequently lags far behind the possible maximum degree of infection thus suggesting artificial distribution of the spores at an earlier date. A great deal is said but very little is actually known about the interrelated effects of such factors as humidity, temperature, and light on the optimum growth of entomophytic microorganisms. As far as I am aware, no one has seriously considered the degree to which microorganisms invade and kill insects which have been weakened by the previous application of insecticides or parasitic insects. Some workers have suggested that certain of the internal symbiotes found normally in many insects may, under certain conditions, become pathogenic, actually harming or killing their host. If such a possibility exists it has not definitely been proved and certainly we have no idea as to the conditions which may bring about this sort of phenomenon.

In the past, most of the work in microbial biological control has been done with fungi, possibly because of the comparative ease with which they may be handled and because of the interest of mycologists in entomogenous fungi. The role of these organisms in the control of insects has been emphasized by Fawcett in a recent review in *Botanical Reviews*. On the other hand, there are still large virgin fields awaiting investigation as concerns the diseases of insects particularly those caused by bacteria, protozoa, and viruses. In this respect, what is the status of these last three groups of infectious agents?

Interest in bacteria parasitic on insects has recently been revived by the use of *Bacillus popilliae* and *Bacillus lentimorbus* in the control of the Japanese beetle *Popillia japonica*. These organisms cause types A and B milky disease. The spores of *Bacillus popilliae* are disseminated over certain areas in northeastern United States and apparently are quite effective in reducing the numbers of Japanese beetle larvae. The point I wish to make is that this is the only instance at present of the practical, relatively wide-scale use of bacteria in the artificial control of insect pests. Surely the opportunities of the field are not limited to this one bacterium. More, much more, fundamental knowledge concerning the basic biological relationships between bacteria and insects is necessary before we can hope to utilize these agents. We have ample evidence that under proper conditions bacteria can and do cause rapid death of insects—but we have practically no information as to what these conditions are or how we can bring them about in the field.

In this connection it is interesting to note that generalizations made by some writers with regard to the use of fungi apparently do not necessarily apply to bacteria and for that matter, probably do not apply to all fungi. For example, White & Dutky found, during the course of their field studies with *Bacillus popilliae*, that it was possible to hasten the disease build-up and subsequent larval reduction by applying the spores in areas where the disease already occurred. It was also possible to prevent the increase of larval populations to their normal peak by introducing the disease agent into areas where the disease did not occur naturally. Once the disease was introduced into an area it was usually permanently established.

There have been well over 100 species of bacteria mentioned in the literature as being pathogenic to insects. Few of these, however, are characterized as true pathogens of insects only, such as is the case with *Bacillus popilliae*. It is obvious that a search should be made for more species of bacteria which are characteristically pathogenic for insects in nature and which, because of this physiological char-

acteristic, may prove to be of more practical value in the hands of man than have those bacteria whose normal habitat is not entomophytic and only occasionally and under certain conditions are pathogenic for insects. Furthermore, and in contrast to what has been done in the past, steps should be taken to maintain and preserve the type cultures of the entomophytic bacteria at a central laboratory such as that of the American Type Culture Collection.

Although the number of protozoa known to cause fatal diseases of insects is smaller than the number of bacterial and fungous diseases, they nevertheless may be more important from this standpoint than they are usually given credit for being. Paillot has expressed the belief that protozoa play a more important rôle than bacteria in the natural destruction of insect pests, though this may be an overestimation of their effect.

Pébrine, the notorious microsporidian disease of silkworms, illustrates how devastating a protozoan disease may be under the proper circumstances. The microsporidian diseases appear to be the most important protozoan diseases affecting insects—there being approximately 125 species of insects known to be susceptible to infection by them. Of this group of Sporozoa the genera *Nosema*, *Thelohania*, *Glugea*, and *Perezia* are probably the best known.

At the present time I know of no protozoan disease which is being used artificially to control insects. There are certain characteristics of protozoa, however, which would make them ideal agents for this type of thing. I refer especially to the fact that most protozoa form very resistant spores or cysts which, while they are awaiting a host, should enable them to withstand unfavorable environmental conditions. This characteristic should also make it relatively easy to distribute them. Offhand, at least, it would seem that the physical environment is much less important in the transmission of protozoan diseases than in that of some of the bacterial diseases. Also to be mentioned is the fact that once a protozoan, such as a microsporidian, contacts or enters the digestive tract of its host, the chances that it will invade the insect's tissues is great. In the case of many bacteria, however, their action is quite destructive once they have gained entrance into the hemolymph or some vital tissue but their initial invasive power, such as through the intestinal epithelium, may be very low.

There are many instances in which virus diseases have been observed to wipe out large infestations of destructive insects dramatically and within a short time. There is no doubt that these diseases (also known as "wilts" or "polyhedral diseases") could be an important means of control if properly handled. As stated by Sweetman, "Under favorable conditions they accomplish a greater reduction of the pests than do the combined efforts of all hymenopterous and dipterous parasites superimposed upon spraying and other control measures." Extensive natural epidemics have occurred among such destructive insects as the gypsy moth, nun moth, armyworm, cutworm, tent caterpillars, and others. Virus diseases also affect beneficial insects such as in the case of sacbrood of bees (a non-polyhedral disease) and jaundice of silkworms (a polyhedral disease).

Since virus diseases break out in rapidly spreading epidemics it would appear that it might be a relatively easy matter to establish such diseases and to cause epizootics at will. Such, however, has not been the case. At least, extensive epizootics have never been produced artificially. Very probably the reasons for the lack of success so far is our woefully inadequate understanding of these diseases. Here is a field awaiting further investigation in order that we may be furnished with more basic facts relating to their probable use against destructive insects.

I have mentioned the state of affairs as it exists with entomophytic bacteria, protozoa, and viruses. I should like to emphasize again that the group of microorganisms so far having had the most practical use is that of the fungi. Since several other writers have pointed out the usefulness of this group, I have taken this opportunity to indicate the other types of microorganisms which have not had as much attention as the fungi but which, when we know more about them, may hold equally as much promise. It is perhaps desirable that we think not only in terms of one microorganism at a time but also keep in mind the possibility (as yet practically unexplored) of using two organisms or species of two different kinds

of organisms simultaneously or of using one kind of microorganism during one stage of the insect's life cycle and another microorganism at a subsequent stage. It is also possible that microorganisms could be used at one stage and a parasitic or entomophagous insect at another stage.

On this whole question of the use of microorganisms in the biological control of insects I should like to make my position perfectly clear. Putting it simply, my attitude is one of hopeful conservatism. I do not envision microorganisms as the panacea to insect control. On the other hand, I do not feel as pessimistic as do some who are willing to throw the whole thing overboard and forget about it. For the present, I am content merely to express the hope that in a few worthwhile instances the artificial dissemination of disease organisms under the proper conditions may aid in at least the partial or seasonal reduction of certain insect populations. Furthermore, I am willing to believe, in some cases at least, that while the diseases may rarely produce a sudden and dramatic destruction of insects, nevertheless, once established in an area certain diseases may maintain themselves and take a small but significant toll of insects year after year. It is entirely possible that with a better understanding of certain of the diseases and with their proper handling we may be able to obtain inexpensively, a rapid and marked reduction of certain insects which cannot be obtained by any other means. As Roger C. Smith has said: "As this method [*i.e.* the use of insect diseases] is so cheap and so easy in the hands of mother nature, it is to be expected that attempts to master it for man's use, in place of more expensive and more inconvenient control measures, should be made repeatedly."

As I see it, the important thing in this whole matter is whether or not we are willing to spend the time, money and energy necessary to accomplish the results of fundamental research in this field. If we are not willing to do this, then we cannot expect to derive very much practical usefulness from it. This, of course, applies not only to the field of biological control but to the entire subject of insect pathology and microbiology even though the applications to agriculture, medicine, and general biology are already many and important. To be a useful member of the sciences employed by entomology, insect pathology should be recognized as a distinct field in its own right. No longer can we make substantial progress by the hit-and-miss methods of the past. What is urgently needed is the sympathetic, moral, and financial support of basic research into the various biological relationships existing between insects and microorganisms, and into the many factors concerned in the spread of diseases among insects in the field. There must also be a systematic search for new diseases occurring naturally among insects and which with the proper techniques may be put to practical use. We have placed the cart before the horse by jumping ahead to obtain as many of the practical benefits from the field as we could without paying for them in terms of good, sound research. The few initial investigations have for some time been yielding diminishing returns. We must now go back and build a scientifically firm foundation of fundamental knowledge to place under the flimsy structure which we have on our hands at present. Having this foundation, then and only then, can we build a structure of broad and practical usefulness to man in his efforts to control the insect pests which plague him and his world.—6-19-45.

Revisions of State quarantines on account of cherry fruitflies.—The cherry fruitfly quarantine of California was revised effective June 17, 1945; those of Idaho, May 1, 1945, of Oregon, June 15, 1945; and that of Washington, May 23, 1945. The revision of the interstate quarantine of California added the counties of Nez Perce, Idaho; and Hood River and Wasco, Oregon to the infested area and removed the County of Whitman, Washington. Revisions of the intra- and interstate quarantines of Idaho added to the infested areas the counties of Kootenai and Nez Perce, Idaho; and Asotin and Kittitas, Washington; and removed the county of Wallowa, Oregon. Revisions of the intra- and interstate quarantines of Oregon added to the infested areas the counties of Kootenai and Nez Perce, Idaho; Hood River and Wasco, Oregon; and Asotin, Klickitat, and Yakima, Washington. The revision of the Washington State quarantine added to the infested areas the Counties of Kootenai and Nez Perce, Idaho; Hood River, Union, and Wasco, Oregon; Klickitat, Skamania, and Spokane, Washington, and parts of the Counties of Asotin and Yakima, Washington. The Washington State revision also removed from the infested area the counties of Coos and Malheur in the State of Oregon.

SCIENTIFIC NOTES

The Bloodsucking Habits and Growth of Nymphs of *Triatoma gerstaeckeri*

D. C. THURMAN, JR., *Texas State Health Department, Austin*

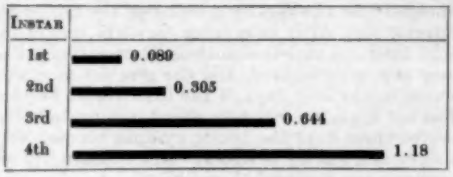
Experiments were conducted by the author in an effort to obtain information about the growth of nymphs of *Triatoma gerstaeckeri* and facts concerning the amount of blood taken by these nymphs in each instar.

It was decided that bugs would be allowed to molt and at the first feeding following the molt the weight recorded before and after feeding. A random sample of these freshly molted bugs was weighed, allowed to take blood from a rabbit and reweighed to obtain the weight of the blood engorged.

Each bug was isolated in a small glass vial with a folded piece of filter paper inside the vial to absorb excess moisture and fecal material and to provide a place for the bug to crawl. In order to weigh the bugs, a vial just large enough to hold a single insect was used. The weight of this vial was carefully checked at numerous times during each series of weighings and any change in the weight of the vial taken into account in computing the gain in weight of each bug.

Average Gains.—In table 1 the column entitled "Amount of Blood Taken" is the average gain in weight of the bugs represented in milligrams of blood at the first feeding following hatching (first instar), or the first feeding following moulting in the remaining instars. The column entitled "Per cent Gain" is obtained by dividing the amount of blood taken by the weight of the unfed bug. The "Per cent Blood in Fed Bug" is obtained by dividing the amount of blood taken by the weight of the bug after feeding.

By use of the figures in table 1 on the average gains in body weight of nymphs of *Triatoma gerstaeckeri* and the table on the average length of each instar, it is possible to determine the average stadia growth per day of *T. gerstaeckeri* in each instar.



This daily increase in body weight (in milligrams) is as follows: First instar, 0.089; Second instar, 0.305 third instar, 0.644 and Fourth instar, 1.18.—5-25-45.

Table 1.—Blood feedings of *Triatoma gerstaeckeri* nymphs.

Instar	No. Bugs Weighed	Weight Before Feeding	Weight After Feeding	Amount of Blood Taken	Per Cent Gain	Per Cent Blood in Fed Bug
1	17	.75	4.65	3.90	520.00	83.89
2	23	2.53	11.16	8.63	341.10	77.32
3	21	10.17	44.60	34.43	338.54	77.19
4	22	37.24	94.00	56.76	152.41	60.38
5	26	93.83	286.13	192.30	204.94	67.21

Table 2.—Highest gains recorded for any one bug in each of the five instars during the experiment.[1]

Instar	Weight Before Feeding	Weight After Feeding	Amount of Blood Taken	Per Cent Gain	Per Cent Blood in Fed Bug
1	.75	6.90	6.15	820.00	89.13
2	2.30	16.80	14.50	630.00	86.30
3	7.90	56.00	48.10	608.86	85.89
4	20.94	96.68	75.74	361.70	78.34
5	78.80	371.04	292.24	370.86	78.76

[1] The weights before feeding as recorded in table 2 are lower than the average weight for bugs in the corresponding instar in table 1. The weights after feeding are higher in table 2 than table 1.

The Biology of *Triatoma gerstaeckeri*

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Laboratory studies were made of the biology and bloodsucking habits of *Triatoma gerstaeckeri* (Stål) from June, 1942, through December, 1943. Colonies of these insects were kept in 400-ml. beakers containing strips of blotting paper folded and placed upright in the beakers. The blotting-paper gave the bugs a hiding place and absorbed excess moisture and fecal material. The beaker was closed by a square of cloth drawn tightly across the top and held by a rubber band. The bugs were fed on half-to-full-grown rabbits which were shaved and strapped to a board. Rubber bands were used to fasten the beakers snugly to the rabbits' backs until the bugs had engorged.

The *Triatoma* used in this study were obtained from eggs laid by adults collected in the field in 1942. The bugs began their adult life in January, February, and March, 1943. This colony consisted of 362 adults in April, 1943. Eggs were collected weekly from each beaker. To determine the average number of eggs laid by female *T. gerstaeckeri*, males and females were confined in beakers in groups of twenty. The highest number of eggs was produced by this species during the months of May and June.

The total number of eggs laid during the season, April 1 to October 31, 1943, was 34,850. After October 31, only occasional eggs were laid. The average number of eggs per female during the period was 11.14 in April, 70.14 in May, 63.13 in June, 50.94 in July, 15.29 in August, 19.18 in September, and 16.53 in October.

The number of eggs per female for the seven months period of observation averaged 245.35. As some of the females died during the study, a record was kept of the number of females studied each month. They were as follows: May 181, June 170, July 97, August, 92, September 88, October 88.

Egg production records on two females kept in isolation, each with male companion, were taken as follows, beginning May 10:

1. May 86, June 150, July 113, August 45, September 82, October 26. (Died October 10.) Total 502 eggs for 152 day period.

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[2] The author is indebted to Lt. T. McGregor, Sn. C. AUS., formerly entomologist for the Texas State Health Department Laboratories, for many suggestions which formed the basis of this study.

2. May 74, June 145, July 90, August 68, September 23. (Died September 30.) Total 400 eggs for 132 day period.

The incubation period of eggs from April through September was 15 to 18 days, usually 16. Nymphs emerged from the eggs by pushing off the cap on the anterior end. After emergence they are very white until their exo-skeleton hardens. During this period they are easily injured, and the greatest mortality occurs in the first days of the first instar. Feeding does not begin immediately after hatching, but after two or three days the young nymphs become very hungry and will try to feed at every opportunity until they have engorged themselves.

In studying the nymphal life and the duration of the stadia, single nymphs were isolated in glass vials. Records were kept of the feedings and the molts. The bugs were reared under conditions of laboratory room temperature and humidity which approximated the conditions affecting the life cycle of members of this species infesting houses. At 3- to 5-day intervals the vials were strapped to the shaved back of a rabbit and the bugs allowed to take a blood meal.

The following results were obtained:

Table 1.—Length of instars of *Triatoma*.

	Days in Each Instar				
	1st	2nd	3rd	4th	5th
Highest record[1]	33	33	63	65	
Average (17)	20	25	42	48	60–120[2]
Lowest record	15	16	26	32	

[1] Highest record and lowest record refers to the longest and shortest period recorded for any one bug in any one stage. The average was taken of seventeen bugs that successfully reached the fifth instar.

[2] This figure is an approximation of the limits of the fifth stadia made during 1942 on a large number of bugs.

In nature eggs and first instar nymphs can be found in all months except January, Febuary, and March. During almost all other months of the year there is an overlapping of stages. The whole cycle slows during the winter, and growth is slow with fewer feedings necessary. The result is that the length of the stadia, particularly the fourth and fifth, varies according to the season. For example, all instars are lengthened during the winter months, but in February and March growth accelerates so that third, fourth, and fifth instar bugs become adults in the early spring and begin laying eggs in April and May.

Hot summer and fall weather apparently lengthens the time spent in the last instars though bugs in the earlier instars grow well if they are able to obtain blood meals frequently.

It was noted in this study that under what appeared to be the same conditions, the length of instars of individual bugs varied considerably. Under adverse conditions, the nymphal life is greatly extended.

The life of the adults varied from six to eleven months in the laboratory. A few have been kept as long as a year. Whether or not females may lay fertile eggs through two seasons was not determined.

Distribution: in an unpublished paper read before the Texas Entomological Society in 1941, McGregor (1941)[1] stated that *Triatoma* infected with the organism of Chagas' disease had been taken from 17 Texas counties. *Triatoma gerstaeckeri* has been collected as far east as Brazos County and as far north as Williamson. It has been found along the Gulf Coast and in the Rio Grande Valley. Readio (1927) gives Texas and Mexico as its distribution. Records at the Texas State Health Department do not show this species to be found in counties along the Red River or in the Panhandle.—5-25-45.

[1] Unpublished paper.

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Insecticides for Control of the Cotton Flea Hopper

L. C. Fife, A. J. Chapman, and R. L. McGarr,[1]
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Sulfur and a dust mixture of 1:2 calcium arsenate-sulfur applied at the rate of 12 to 15 pounds per acre at 5-day intervals have been the standard insecticides for control for the cotton flea hopper, *Psallus seriatus* (Reuter). In experiments conducted in the Lower Rio Grande Valley of Texas during 1944, these two dusts were compared with 2.5, 5, and 10 per cent DDT-pyrophyllite, 5 per cent DDT-sulfur, and calcium arsenate in the control of this pest.

Three series of field-plot tests were conducted. The plots were replicated in randomized blocks, four 0.10-acre plots in series 1 and 2 at Raymondville, and three 0.20-acre plots in series 3 at Brownsville.

The DDT was obtained in two forms—a mixture of 10 per cent DDT-pyrophyllite which was further diluted to the desired strength, and technical DDT which was pulverized and mixed with sulfur in a local commercial hammer mill.

Only one application was made of each insecticide. The dusts were applied with a single-nozzle rotary hand dust gun early in the morning when the cotton was usually damp or wet with dew and the air for the most part calm.

The infestation records were made by counting the adults and nymphs present in 100 terminal buds per plot at each inspection. Counts were made at intervals over a maximum period of 16 days. The treatments, dosages, and infestation records are given in table 1.

All treatments containing DDT reduced the populations below 20 flea hoppers per 100 terminal buds within 4 to 6 days, and were more effective than the 1:2 calcium arsenate-sulfur mixture, sulfur alone, or calcium arsenate. Calcium arsenate added to 5 per cent of DDT in pyrophyllite did not increase its effectiveness. Although there was considerable reduction in the infestation within 24 hours, in all but one of the DDT treatments the maximum reduction occurred 4 to 6 days after dusting. In series 1 the nymphal population in both DDT treatments remained significantly lower than in the checks for 16 days after dusting, while the population in the sulfur treatment increased about the same as in the check. DDT was effective against the adults for at least 9 to

[1] The authors were assisted in the field by Ivan Shiller, O. L. Walton, and C. A. Richmond. Thanks are due Corinne Baker for assistance in the preparation of the manuscript.

[2] In cooperation with the Texas Agricultural Experiment Station.

Table 1.—Flea hopper infestation in small plots of cotton following one application of various insecticides. Texas, 1944.

Treatment	Dosage, Pounds per Acre	Number of Flea Hoppers per 100 Terminal Buds Before and After Dusting									
		Before		Day after		4–6 Days after		9–13 Days after		16 Days after	
		Adults	Nymphs	Adults	Nymphs	Adults	Nymphs	Adults	Nymphs	Adults	Nymphs
					Series 1						
DDT-pyrophyllite:											
2.5%	12.3	33	50	15	15	8	4	7	11	21	56
5%	11.5	29	42	7	3	9	0	5	10	21	42
Sulfur	12.5	31	42	29	34	11	26	11	21	22	73
Check no treatment	—	28	39	29	52	17	41	10	34	25	80
Minimum significant difference, 5% level	—	—	—	9	12	6	16	5	10	—	18
					Series 2						
5% DDT-sulfur	10.8	28	53	5	11	3	3	11	28		
5% DDT-pyrophyllite	11.2	29	59	1	2	2	3	10	25		
Calcium arsenate-sulfur (1:2)	10.2	31	49	9	31	7	14	10	64		
Check, no treatment	—	24	56	13	41	10	39	16	56		
Minimum significant difference, 5% level	—	—	—	3	12	5	21	4	15		
					Series 3						
DDT-pyrophyllite:											
2.5%	15.6	30	57			13	3				
5%	14.4	29	50			8	0				
10%	14.2	29	53			3	0				
Calcium arsenate plus:											
DDT-pyrophyllite (40:5:55)	14.8	34	51			4	0				
Sulfur (1:2)	17.1	28	54			13	18				
Sulfur	16.3	27	55			14	10				
Calcium arsenate	7.2	29	55			11	23				
Check, no treatment	—	38	57			22	24				
Minimum significant difference, 5% level	—	—	—			6	14				

13 days. Although the 5 per cent DDT-pyrophyllite gave somewhat better control than the 2.5 per cent strength, the data indicate that 2.5 per cent DDT applied at the rate of 12 to 15 pounds per acre would be sufficient and more effective than sulfur or the 1:2 calcium arsenate-sulfur mixture. Further experiments are needed, however, to determine the best dosage and interval of application and the most desirable diluents.—3-30-45.

Effect of Ferric Dimethyl Dithiocarbamate on Emergence of Tobacco Flea Beetles from Plant-Bed Soil

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Gilmore & Levin (1944) have shown that the tobacco flea beetles, *Epitrix hirtipennis* Melsh., attacking recently transplanted tobacco are probably reared in the tobacco plant beds. On the basis of their figures enough first-brood beetles emerged from the soil on 100 square yards of open plant be from May to July, inclusive, to supply a population of 71 beetles per plant on an acre of tobacco. Since beetles of this brood usually begin migrating to the field 1 to 3 weeks after the tobacco is transplanted, and thus injure the plants at one of the most sensitive stages of growth, methods of reducing the initial populations of flea beetles are of much interest.

Attention has been called to the possible insecticidal value of derivatives of dithiocarbamic acid. Ferric dimethyl dithiocarbamate has been demonstrated to be an effective fungicide for blue mold, *Peronospora tabacina* Adam, by Anderson (1942) and others. Guy (1937) found this material to be highly effective for inhibiting the feeding of Mexican bean beetles, *Epilachna varivestis* Muls., and Japanese beetles, *Popillia japonica* Newm. This was later confirmed by Tisdale & Flenner (1942). It is the purpose of this note to report the effect of this material on tobacco flea bettle populations in tobacco plant beds.

Table 1.—Emergence of tobacco flea beetles from soil of a tobacco plant bed sprayed with ferric dimethyl dithiocarbamate alone and in combination with calcium arsenate.

Treatment	Beetles Emerging from 1 Square Foot of Soil		Reduction Due to Treatment	
	1943	1944	1943	1944
	Number	*Number*	*Per Cent*	*Per Cent*
Check (untreated)	73	106	0	0
Ferric dimethyl dithiocarbamate	39	19	47	82
Ferric dimethyl dithiocarbamate plus calcium arsenate	12	5	84	96
Difference required for significance (odds 19:1)	19	63		

The experimental work was conducted at Oxford, N. C., during 1943 and 1944 on replicated plots of approximately 5 square yards in tobacco plant beds to develop a combination spray for the control of blue mold and flea beetles. There were four replicates in 1943 and three in 1944 in randomized blocks. Semi-weekly applications were made by means of a small-type power sprayer at a pressure of 125 to 150 pounds per square inch, as commonly recommended for the control of blue mold. All plots were uniformly inoculated with a viable suspension of conidiospores of the blue mold fungus to assure uni-

form distribution of inoculum. One plot was sprayed with ferric dimethyl dithiocarbamate at the rate of 2 pounds per 100 gallons of water. For another plot calcium arsenate at the rate of 4 pounds per 100 gallons was added to the ferric dimethyl dithiocarbamate spray. A third plot was untreated. In the latter part of May, prior to maturity of the beetle, three cloth cages, each covering 1 square foot of soil surface, were placed in the plots. On alternate days records were made of flea beetle emergence into these cages, and the beetles were removed during each examination.

The data on flea beetle emergence (Table 1) are in agreement for both years, although the reduction was greater in 1944 than in 1943. Ferric dimethyl dithiocarbamate alone significantly reduced the infestation, but when calcium arsenate was added greater reductions were obtained. Both spray mixtures gave highly effective control of blue mold. In transplanting trials, measurement data showed that, although the seedlings sprayed with the ferric dimethyl dithiocarbamate-calcium arsenate mixture at first tended to grow more slowly than those sprayed with the fungicide alone, there were no significant differences in growth 2 months after transplanting.

The appreciable reductions in flea beetle populations in plant beds by ferric dimethyl dithiocarbamate suggest that this is a promising material for use in combination with a more toxic insecticide for dual control of the flea beetle and blue mold.—7-15-45.

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DDT for Control of the Grape Bud Beetle

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The grape bud beetle, *Glyptoscelis squamulata* Crotch (family *Chrysomelidae*), is a serious pest on grapes in the Coachella Valley, California, where it feeds on the opening buds early in the spring (Ebeling 1939). The habit of the beetle that makes it susceptible to treatment with DDT is its diurnal migration from beneath the loose bark of the trunk of the vine, where it hides during the day, to the canes of the vine where it feeds at night. If DDT is applied to the trunk and the stake that is driven into the ground near the trunk in the case of trellised vines, the beetles absorb enough DDT in their diurnal migrations to result in their paralysis and eventual death. The broad, typically chrysomelid tarsi of the beetles, offer a large absorptive surface and are probably a factor greatly favoring control with DDT.

The following materials were used in each of six vineyards: *Gesarol AK-20* (20 per cent DDT) at 5 pounds and 10 pounds to 100 gallons of water, DDT dissolved in kerosene at a concentration of 4 grams to 100 ml. and this solution used at 5 per cent dosage, and dusts containing 5 per cent and 10 per cent DDT, with talc as the diluent. Casein spreader at 4 ounces to 100 gallons was used in all the sprays and the entire vine and stake were sprayed, using a large orchard power sprayer. The dusts were applied with a knapsack duster and were directed only at the trunks and stakes. About 0.8 gallon of spray was applied per vine in each treatment and 0.1 pound of dust. There are usually about 450 vines per acre.

During the months of February and March 1945, both the sprays and dusts were applied once in some plots and twice in others. There was a 12-day interval between the dusts and a 21-day interval between the sprays. Also in a few tests the sprays or dusts were applied only to one side of the vine.

A count of several thousand buds in each plot in six vineyards in which the DDT treatments were applied showed, in all cases in which the treatments were made before the beetles were able to cause any injury, a highly satisfactory control, whatever the form of treatment. Even the single treatments were highly satisfactory although they were applied about two weeks earlier than what proved to be necessary and were followed by two rainstorms which removed much of the DDT.

In a vineyard in which 90 per cent of the buds were destroyed on the untreated vines, a single treatment of 5 per cent dust resulted in such good protection of the buds that only 1.7 per cent were eaten by the beetles. The single spray treatments were no more effective than the dust even though the entire vine was covered with the spray. The treatments with two dusts or two sprays resulted in practically complete protection of the buds.—7-3-45.

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Flea Collections at Army Installations in the Fourth Service Command

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Numerous collections of fleas have been made by Army personnel in the Fourth Service Command during 1943, 1944 and 1945. All specimens were forwarded to the Fourth Service Command Medical Laboratory for identification. The states comprising the Fourth Service Command are Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina and Tennessee.

The collections are summarized in table 1. The following species are represented in the collections: *Ctenocephalides canis* (Curtis), *C. felis* (Bouché), *Echidnophaga gallinacea* (Westwood), *Leptopsylla segnis* (Schonherr), *Pulex irritans* Linnaeus, *Rhopalo psyllus gwyni* C. Fox *Xenopsylla cheopis* (Rothschild). Altogether, 506 specimens, representing 22 localities are included.—8-11-45.

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Table 1.—Flea collections at army installations in the fourth service command.

Species	Locality	Date of Collection	Host	Number of Specimens ♂	Number of Specimens ♀
Ctenocephalides canis	MISSISSIPPI				
	Hattiesburg	15 May 1944	dog	1	
Ctenocephalides felis	ALABAMA				
	Ozark	7 Sept. 1944	rat		1
	FLORIDA				
	Boca Raton	May 1944	dog	3	7
	Carrabelle	1 Apr. 1944		46	77
	Panama City	26 May 1944	cat		1
		24 May 1944	house		2
		22 May 1944	dog		4
	Starke	20 Mar. 1944	house		1
	Tampa	12 June 1944		1	8
		Mar. 1945		1	3
	GEORGIA				
	Albany	14 Oct. 1943		5	
	Atlanta	6 June 1944	dog		30
		30 May 1945	house		1
		31 Aug. 1944		2	2
	Columbus	18 Aug. 1944	building	9	8
		13 July 1944	building	10	11
		29 May 1944	house		6
	Hinesville	26 Oct. 1944			2
	Macon	19 Oct. 1944	dog		2
		21 Aug. 1944	dog		5
	MISSISSIPPI				
	Hattiesburg	15 May 1944	dog		1
		31 July 1944			2
	NORTH CAROLINA				
	Goldsboro	Oct. 1944			6
	SOUTH CAROLINA				
	Myrtle Beach	31 May 1945			1
		29 May 1945	dog	2	
Echidnophaga gallinacea	ALABAMA				
	Ozark	3 Apr. 1944	rat	1	2
		25 Oct. 1944	rat		1
		27 Feb. 1945	rat		1
		Mar. 1945	rat		3
		25 June 1945	rat		1
		25 May 1945	rat		1
		23 Mar. 1945	rat		2
		20 Mar. 1945	rat		3
		Mar. 1945	rat		2
	FLORIDA				
	Panama City	22 May 1944	dog		4
		26 May 1944	cat	3	3
	GEORGIA				
	Bainbridge	Sept. 1943	rat	5	16
	NORTH CAROLINA				
	Fayetteville	3 Sept. 1944	dog		7
	SOUTH CAROLINA				
	Charleston	25 Oct. 1944	rat	3	22
		25 Apr. 1944	rat		3
	Myrtle Beach	17 Nov. 1944	dog	2	18
Leptopsylla segnis	ALABAMA				
	Ozark	25 May 1945	rat	2	
		31 May 1945	rat		1
		23 Mar. 1945	rat		3
		22 Mar. 1945	rat		2
		21 Mar. 1945	rat	1	4
		Mar. 1945	rat		2
		Mar. 1945			2
		28 Feb. 1945	rat	1	5
		27 Feb. 1945	rat		2
	SOUTH CAROLINA				
	Charleston	2 Feb. 1944	rat	2	6

Table 1.—*Continued*

Species	Locality	Date of Collection	Host	Number of Specimens ♂	Number of Specimens ♀
Pulex irritans	FLORIDA				
	Starke	20 Mar. 1944	house	19	11
	MISSISSIPPI				
	Hattiesburg	15 May 1944	dog	5	9
Rhopalopsyllus gwyni	FLORIDA				
	Tampa	25 May 1945	rat	2	1
Xenopsylla cheopis	ALABAMA				
	Daleville	17 Aug. 1944		1	2
		19 Aug. 1944		1	1
	Ozark	15 Aug. 1944	rat	2	4
		7 Sept. 1944	rat	5	1
		11 Sept. 1944	rat	1	1
		25 Oct. 1944	rat	1	4
		25 June 1945	rat	1	
		31 May 1945	rat		1
		12 May 1945	rat		1
		26 Mar. 1945	rat	1	4
		20 Mar. 1945	rat	2	2
		22 Mar. 1945	rat		3
		21 Mar. 1945	rat		1
		20 Mar. 1945	rat	1	5
		19 Mar. 1945	rat	4	
		28 Feb. 1945	rat		1
		27 Feb. 1945	rat		1
	Selma	7 July 1944	rat	7	10
	FLORIDA				
	Tampa	8 May 1945	rat		2
	GEORGIA				
	Atlanta	10 Sept. 1943	rat	3	4
	Bainbridge	Sept. 1943	rat		2
	SOUTH CAROLINA				
	Charleston	25 Apr. 1944	rat		1
		5 May 1944	rat		1
		11 Aug. 1944	rat	1	7
		18 Aug. 1944	rat	3	11
		21 Aug. 1944	rat	1	7
		10 Sept. 1944	rat	12	14
		Oct. 1944	rat	3	1
		17 Oct. 1944	rat	9	2
		25 Oct. 1944	rat		1

Control of Housefly Breeding in Partly Digested Sewage Sludge

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Sewage plants operating under optimum conditions experience no difficulty with respect to the breeding of the housefly, *Musca domestica*, in the sewage sludge. However, under certain unfavorable operating conditions it frequently becomes necessary to withdraw sludge before it has been completely digested. This type of sludge which is often referred to as "green sludge" will not dewater readily and offers an ideal environment for housefly breeding. When a problem of this kind occurred in one of the Eighth Service Command installations, a rotenone water-emulsifying solution was recommended by the manufacturer as a larvicide. A sample of the material was sent to this laboratory for the purpose of testing its comparative efficiency.

Sludge used in this experiment consisted of equal parts of freshly drawn, completely digested sludge and "green sludge." Inasmuch as this material was too high in moisture content, it was dewatered by suspending it in a cloth bag overnight. The sludge was then divided into 24 equal portions of approximately 250 ml. each and put in glass jars. Maggots used in these tests were reared in an artificial medium consisting of 1 part ground whole oats, 2 parts ground alfalfa and 5 parts of wheat bran moistened with a solution made up of 1 teaspoonful each of dried yeast and *Maltine*[3] in 1 liter of water. One hundred healthy, third instar larvae produced in this medium were placed in each jar of sludge. The

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[3] *Maltine, plain*—A concentrated extract of malted barley and of wheat and oats. Maltine Company, New York.

Table 1.—Emergence of housefly larvae from "green" sewage sludge treated with various larvicides.

	Treatment	Larvicide Applied per 100 Sq. Ft.	Larvicide Applied per Cubic Foot	Per Cent Emergence Based on 100 Larvae per test	Number Pupated But Not Emerged From Puparium
A	Control stirred	—	—	64	9
B	Control strirred	—	—	88	8
A	Control not stirred	—	—	60	22
B	Control not stirred	—	—	87	6
	Average for Controls	—	—	74.75	11.25
A	30% Borax Solution stirred	2.93 gal.	0.15 gal.	0	0
B	30% Borax Solution stirred	2.93 gal.	0.15 gal.	0	0
A	30% Borax Solution not stirred	2.93 gal.	0.15 gal.	0	0
B	30% Borax Solution not stirred	2.93 gal.	0.15 gal.	0	0
	Average for Borax	2.93 gal.	0.15 gal.	0	0
A	10% DDT dust stirred	14.77 lbs.	0.75 lbs.	5[1]	23
B	10% DDT dust stirred	14.77 lbs.	0.75 lbs.	2[1]	26
A	10% DDT dust not stirred	14.77 lbs.	0.75 lbs.	1[1]	20
B	10% DDT dust not stirred	14.77 lbs.	0.75 lbs.	2[1]	49
	Average for DDT Dust	14.77 lbs.	0.75 lbs.	2.5[1]	29.5
A	0.25% DDT emulsion stirred	2.93 gal.	0.15 gal.	66	5
B	0.25% DDT emulsion stirred	2.93 gal.	0.15 gal.	71	0
A	0.25% DDT emulsion not stirred	2.93 gal.	0.15 gal.	71	16
B	0.25% DDT emulsion not stirred	2.93 gal.	0.15 gal.	82	9
	Average for DDT emulsion	2.93 gal.	0.15 gal.	72.5	7.5
A	0.05% rotenone emulsion stirred	2.93 gal.	0.15 gal.	76	6
B	0.05% rotenone emulsion stirred	2.93 gal.	0.15 gal.	74	6
A	0.05% rotenone emulsion not stirred	2.93 gal.	0.15 gal.	85	2
B	0.05% rotenone emulsion not stirred	2.93 gal.	0.15 gal.	75	9
	Average for rotenone emulsion	2.93 gal.	0.15 gal.	77.5	5.75
A	Kerosene stirred	2.93 gal.	0.15 gal.	0	0
B	Kerosene stirred	2.93 gal.	0.15 gal.	0	0
A	Kerosene not stirred	2.93 gal.	0.15 gal.	0	0
B	Kerosene not stirred	2.93 gal.	0.15 gal.	0	0
	Average for Kerosene	2.93 gal.	0.15 gal.	0	0

[1] Flies which emerged died within two hours.

larvae were then allowed a 5-hour period to adjust themselves to the new environment before the larvicides were applied.

The 24 jars were divided into six groups of four each; five groups were treated with the larvicides; those remaining constituted the control. Inasmuch as under actual field conditions a crust is usually formed over this type of sludge, it was believed that mere surface application might not be effective and that a thorough mixing of the larvicide with the sludge might be needed. Therefore, the larvicides were thoroughly stirred into the sludge of half of the jars while it was simply applied to the surface in the remainder. The controls were treated similarly except that no larvicide was added.

Because they were readily available to Army installations, the following larvicides were selected for comparison with the submitted rotenone sample: borax, DDT emulsion, DDT dust and kerosene. *Twenty Mule Team Borax* was applied as a 30 per cent solution (by weight). The DDT emulsion was prepared by adding 5 parts of 5 per cent DDT in kerosene to 10 parts of *Triton 770* and 85 parts of water. The DDT dust was the standard larvicide powder which is composed of 10 per cent DDT and 90 per cent talc. The final rotenone emulsion was made by adding 5 parts of the 1 per cent concentrate to 95 parts of water in accordance with the manufacturer's recommendation.

The results obtained with these tests and given in table 1 idicated that the rotenone and DDT emulsions had very little larvicidal value. However, a 100 per cent kill was obtained with both borax and kerosene. It may be noted further that although DDT dust was only moderately effective as a larvicide, it may be expected to accomplish the control

Table 2.—Emergence of housefly larvae from alfalfa-bran-yeast culture medium treated with relatively low concentration of 10 per cent DDT dust.

Treatment	Larvicide per 100 Sq. Ft.	Larvicide per Cubic Foot	Total Larvae Used	Flies Emerged	Flies that Pupated But Did Not Emerge	Flies Alive 2 Hours After Emergence
				Per Cent	*Per Cent*	
Control	—	—	256	95.3	4.7	all
10% DDT dust	0.97 lbs.	0.05 lbs.	394	43.4	44.7	none
10% DDT dust	1.94 lbs.	0.10 lbs.	450	21.3	70.2	none

desired. This statement is based on the fact that most of the pupae produced failed to emerge and that the few adults that did emerge were dead within 2 hours.

In view of the popularity of DDT, an additional check of the larvicidal value of this material was made under slightly different circumstances, using much lower concentrations of the dust. Since a comparable sludge was not available for this check, the test was made on maggots in the bran-alfalfa-yeast culture medium referred to in the description of methods, and routinely used in rearing. Although this material is not an exact duplication of the sludge, it has many similar physical characteristics. The results obtained are tabulated in table 2. Although the lower concentrations of DDT dust used here did not prevent pupation and some emergence of the flies, they did accomplish ultimate control in that the adults which emerged died within 2 hours.

The data presented indicate that a rotenone emulsion used as recommended by the manufacturer did not control housefly breeding in sewage sludge as well as borax, kerosene or DDT dust. DDT emulsion at the strength used was no better than the control. Additional data show that the application of 10 per cent DDT dust may be reduced from approximately 15 lbs. to 1 lb. per 100 sq. ft. if ultimate control rather than prevention of emergence is considered adequate.—9-7-45.

Thanite as a Control for Ants

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In December, 1944, Dr. Hosmer W. Stone, Associate Professor of Chemistry, University of California at Los Angeles, told me of a casual observation he had made with *Thanite* in the control of ants. He sprayed an ant nest with undiluted *Thanite* and found it was highly effective in killing all ants that appeared for a considerable period following the application. Pursuant to the clew as to the possible value of *Thanite* in ant control, I have made numerous simple tests and the results indicate this material may serve a useful purpose in controlling ants of the type that invade houses and are a nuisance on home grounds.

The possible value of *Thanite* is indicated by the following observations: A bit of cotton wrapped to the end of a toothpick was dipped in *Thanite* and the excess liquid removed by smearing the end of the toothpick against the neck of the bottle. The end of the toothpick was then drawn across the path of the ants, depositing a very thin smear of *Thanite* about one-eighth inch wide. Sometimes the hole through which the ants entered the kitchen was circled and sometimes an L-shaped or maze-like line was made across their trail. The ants stopped suddenly at the line and turned back, or raced back and forth along the line. It appeared, however, that eventually all of them, in their distraction or bewilderment, got some of the material on a foot or antenna. Those observed to touch the line became markedly affected, exhibited paralytic effects and died after a few hours. In many tests made, hundreds of dead ants were found the following morning and the invasion of ants had completely disappeared. Undiluted *Thanite* atomized on nests of the Argentine ant, *Iridomyrmex humilis* Mayr., resulted in eliminating all ants for a period of several days. Invasions of ants into houses have invariably been stopped immediately by the atomizer method of application. The ants are markedly affected by the odor of the *Thanite* but lethal action seems to result primarily from the direct contact of the material with the feet or antennae.

Thanite is a product of the Hercules Powder Company, covered by U. S. patent 2,217,611 and is described as secondary terpene alcohol thiocynyl acetate. A 3 per cent solution of *Thanite* in highly refined kerosene has been in use for several years as a spray against household pests such as flies, mosquitoes, bedbugs and silverfish. The killing action results from the spray mist that falls directly upon the body of the insect.—8-28-45.

Duplicating Japanese Beetle Injury in Field Corn[1]

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Japanese beetles annually invade corn fields in southeastern Pennsylvania during July while field corn is being pollinated. The destructive habits of the beetles congregating on ear silks, feeding thereon and cutting the silks down to the husk, prevent pollination to varying degrees. If silks are kept sheared off during pollen flow, fertilization will not be accomplished, or if it is, only sparsely, presenting an appearance as shown in figure 1.

There is some question as to typical Japanese beetle injury in field corn. Other types of injury such as drought may tend to cause similar injury appearance. In order that such injury could be more nearly evaluated, hybrid C-88 was used in an effort to duplicate Japanese beetle feeding by cutting silks at periodic intervals after pollination.

In all cases, developing ears were covered with

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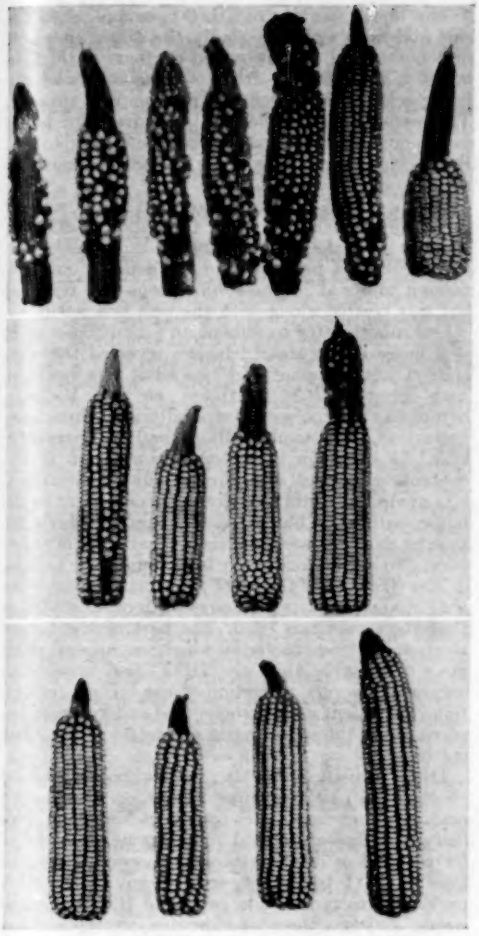

FIG. 1 (above).—Injury resulting in field corn through lack of fertilization when silks cut off 6 hours after pollination.
Middle.—Injury resulting in field corn when silks are cut off 7 hours after pollination.
Below.—Injury resulting in field corn when silks cut off from (left to right) 12 hours, 24 hours, 36 hours and 48 hours after pollination.

glassine bags before silks appeared. When the silks were numerous and receptive, each ear was artificially pollinated by pouring collected C-88 pollen over the silks and immediately re-covering the ear with the glassine bag. At periods ranging from 6 to 48 hours after pollination, the glassines were removed and the silks plus an inch of husk were cut off with a clean knife. This duplicated the injury of the Japanese beetles and was as severe as any usually found in the field.

A clean glassine was then placed over the treated ear and further protected till harvest by a paper pollinating bag.

Figure 1 (above) shows the results obtained when silks were cut 6 hours after pollination. In this case fertilization was spotty and simulated typical beetle injury as found in the field. The abnormal rounded kernels are typical in a sparsely fertilized ear.

Figure 1 (middle) shows the results when silks were cut 7 hours after pollination. With only one additional hours' fertilizatilon time, the ears were well fertilized. Some injury similar to typical beetle injury appeared at the ear tip and base.

In figure 1 (below), are shown ears in which silks were cut at periods of 12 to 48 hours. In all four cases, fertilization was very good. The ears were well filled out with the exception of the tips. This injury was also apparent in check ears and cannot be considered as caused by Japanese beetles. This injury is normally found in corn grown out of beetle areas.

This preliminary work has shown that typical Japanese beetle injury can be duplicated artificially. The point of perhaps greatest interest is the time factor involved. With C-88, heavy injury resulted when silks were removed within six hours after pollination, and only light injury resulted after 7 hours. Injury after 12 hours was not apparent, and the ears could not be distinguished from check ears. This tends to indicate that Japanese beetles must remove silks from ears within 6 to 7 hours after pollination to cause injury.—4-4-45.

Factors Inducing Diapause in the Oriental Fruit Moth

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While growing the Oriental fruit moth *Grapholitha molesta* (Busck.), for experimental purposes in small green apples in the laboratory during the winter of 1943–1944, we encountered the difficulty of having a high percentage of the larvae go into diapause even though grown at 80° F. Many experiments were conducted to study the various factors that might influence diapause in this insect. These showed that whether or not the Oriental fruit moth goes into a diapause is determined by:

1. The number of hours of light per day during the larval feeding period.
2. The temperature during the larval feeding and prepupal periods.

The effect of light as shown in two experiments is presented in table 1. As is shown, the percentage of larvae going into diapause increases with the increasing number of hours of light per day up to about 12 hours but decreases abruptly to almost none at 15 hours or more of light per day. This low percentage of diapause under conditions of long hours of light per day agrees with the work of Baker (1935) on tree-hole mosquitoes. In the case of the Oriental fruit moth light operates throughout the larval feeding period, the effect being cumulative with apparently no critical point during the period.

Table 1.—The percentage of diapause induced in Oriental fruit moth larvae grown at 70° and 80° F. by various numbers of hours of light per day. All larvae were grown in green apples and held at 70° F. after emergence.

TEMP. DEGREES F.	HOURS LIGHT (25 FOOT CANDLES) PER DAY						
	0	6	9	12	15	18	24
	Per cent of larvae entering diapause						
70	15.2	94.4	100.	98.0	2.8	4.5	14.3
80	0.8	61.5	80.9	92.6	5.2	0.0	1.1

This reaction to light agrees with field experience since the Oriental fruit moth enters hibernation during the late summer and fall, often while the weather is still warm.

Low temperatures during the larval feeding and prepupal periods increase the percentage of diapause.

By the use of this information large numbers of the Oriental fruit moth were grown very satisfactorily in the laboratory through the winter of 1944–1945. Two 200-watt tungsten-filament electric lamps were kept burning continuously in the room where the larvae were feeding and the temperature was kept at 76 to 80 degrees F. Under these conditions there was no appreciable amount of diapause.

This preliminary note is published in hope that it may be of value in the laboratory rearing of this and similar insects and because the importance of other work may delay the completion of the study.—7-15-45.

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DDT and Bedbugs in Chicken Houses

WALTER M. KULASH[1] and J. MYRON MAXWELL[2]

DDT (dichloro-diphenyl-trichloroethane) has already been reported as an effective control for bedbugs (Madden *et al.*, 1944). Preliminary reports indicate that DDT not only has a high degree of toxicity to bedbugs but also that it is a good residual insecticide. In the poultry house, DDT has been used for the control of larval and adult flies (Wolfenbarger & Hoffman 1944).

In the early spring of 1945, a severe infestation of bedbugs in chicken houses was located on a farm near Raleigh. The bedbugs have been identified by Mr. H. S. Barbour and C. F. W. Musebeck of the U.S.N.M. as *Cimex lectularius* L. Three of the chicken houses have been in use continuously for over fifteen years and have had bedbugs in them most of these years. At the time of treatment each of these three houses contained about three hundred chickens. The other two houses have not been used for the past six months, but nevertheless, are heavily infested with bedbugs. Four of these houses were treated and shortly after treatment one of the unused houses was again occupied by fifteen chickens.

Prior to treatment, the "pine straw" nesting material from one of the next boxes was removed for examination. A count of live bedbugs in this material (which lined a typical nest box 12×12×6 inches to a depth of 2 inches) showed that there were 380 bedbugs present. Most of the bugs were in the nymphal stage.

The houses were treated with a 5-per cent kerosene solution of DDT on April 3. Nest boxes in three of the houses were cleaned out and the contents burned before they were treated. In these three houses the nest boxes, of wooden sides and bottom, were arranged in a row underneath a dropping board 3 feet above the floor of the house. Roost poles 2 inches in diameter were suspended 16 inches above the dropping board.

The liquid solution of DDT was applied to the side and back walls, the roosts, the dropping board, nest boxes, and the uncovered portions of the feed boxes. Chickens were driven to one corner of the house while the unoccupied portion was sprayed. The material was applied with a barrel-type pump and enough of the liquid was used in order to wet the surface of the area being treated without any run off on vertical surfaces.

In the fourth chicken house, nest boxes were of the same size as in the other three, but of different constructions, the bottom being made of 1-inch mesh wire instead of being a solid wooden bottom. The nesting material in these boxes was not removed but was treated along with the nest box itself.

One month after treatment an examination of 20 nest boxes in the treated houses revealed the presence of one nymphal and two adult live bedbugs. Two months after treatment no live bedbugs, nymphs or adults, were found although there were indication that some bedbugs had been recently killed. A thorough laboratory examination of the contents of one nest box showed only one dead bedbug nymph. Control of bedbugs was excellent in the house with wire bottom nest boxes in which the nesting material was not removed at time of treatment. No live bedbugs have been found here to date.

The efficiency of the DDT treatment far surpasses that of any previous treatment with other materials that the owner has tried. The best of the former treatments (waste motor oil which was applied much more thoroughly than the DDT) had resulted in only a temporary reduction of the bedbug population. Treatment with carbolic acid and kerosene has given about the same degree of control as the waste motor oil.

DDT, as used in this test, has had no detrimental effect on the chickens. Since the time of treatment a number of mice have been found dead or dying. This can probably be ascribed to the presence of DDT for no dead or dying mice were observed before the time of DDT treatment, or after any of the other previous treatments. The adults of the dark mealworm, *Tenebrio obscurus* Fabricius, were present in considerable abundance in the feed room before DDT was applied. However, the DDT treatment has been very effective in killing them.

SUMMARY.—5-per cent DDT dissolved in kerosene has proved an excellent control for bedbugs in chicken houses. In three houses the back and side walls, roost, wooden nest boxes, with nesting material cleaned out previous to treatment, and the exposed portions of feed boxes were treated. In the fourth house, the nesting material contained in wire bottom nesting boxes was not removed before treatment. Two months after treatment no live adult or nymphal bedbugs have been found in any of the treated houses.—7-14-45.

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The Effect on the Fingers of the Poison of *Formica exsectoides*

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During the handling of *Formica exsectoides* Forel in the winter months the skin of the tips of the fingers, especially under the nails of thumb and first finger, becomes hardened. After a few days the skin loosens and peels off. If there are abrasions on the skin, the poison produces a burning sensation similar to that caused by many acids.

In the spring during one day some 1200 workers were picked up singly or a few at a time. The handling was done mostly with the thumb and first finger. The ants ejected their poison quickly and freely. The reaction on the skin was much more severe than it had been during the winter. The skin of the thumb and first finger soon became yellowish brown in color. The skin was stiff and the ends of the digits were numb. Although there were no breaks in the skin the area around the nails became painful. After about 3 hours of almost constant picking up the ants, the thumb and first finger ached severely. The hands had been rinsed in water at intervals during this time and later were washed with soap but the ends of the fingers remained discolored and the tips painful.

Gradually the pain subsided when the fingers were at rest. For 5 hours any pressure such as holding a pencil, produced pain. The next day the thumb and first finger felt bruised and were tender although not painful when not in use. One millimeter below the line where nail and skin join at the tip of the finger an irregular purple line had developed. This line took 18 days to disappear. On the fifth day the skin on the end of the thumb and first finger came loose in blister-like patches. The next day the loosened skin sloughed off in pieces. Purple spots were noticeable under the edge of the nail. By the seventh day the skin on the ends of these digits had entirely peeled off to the normal skin.

The poison of *F. exsectoides* is produced and stored in a sac in the posterior dorsal part of the gaster and is ejected by the worker as a means of defense, for anesthesia or according to Peirson to kill seedlings. Frequently the excited worker grasps any object with her mandibles and directs a fine stream of the clear liquid poison on the spot being bitten. In order to accomplish this she directs her gaster forward under the body.—6-5-45.

DDT and Lead Arsenate Compared for Control of the Pecan Nut Casebearer

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Field and laboratory tests were conducted in 1944 to compare DDT (1-trichloro-2,2-bis(*p*-chlorophenyl)ethane) with lead arsenate when applied as sprays for the control of the pecan nut casebearer, *Acrobasis caryae* Grote. For all tests technical DDT was mixed with pyrophyllite at the rate of 1.5 pound, of each per 100 gallons of spray. The DDT was sifted and then throughly mixed with the pyrophyllite in a rotary mixing machine. The product did not mix readily with water, and the suspension in the spray tank was not entirely satisfactory. Lead arsenate (acid) was used at the rate of 6 pounds per 100 gallons.

FIELD TESTS.—The sprays were applied to pecan trees of the Burkett variety on May 23 at Comanche, Tex. Most of the trees bore an excessive crop of poorly filled nuts. The casebearer infestation was rather light. Approximately 26 per cent of the first-degeneration eggs observed on May 22 had hatched. Each treatment was replicated 10 times on single-tree plots.

On half the trees sprayed with DDT and on all the trees sprayed with lead arsenate zinc sulfate was included at the rate of 3 pounds per 100 gallons, to control pecan rosette. The check trees were sprayed with this material alone.

The criterion used in determining the effectiveness of the spray treatments was the percentage of nuts retained in 50 tagged clusters per tree (1625 to 1700 nuts per treatment at the start) at the end of the feeding period of the first-generation larvae and at harvest. The results are summarized in table 1.

Table 1.—Comparative effectiveness of lead arsenate and DDT for control of the pecan nut casebearer.

TREATMENT	NUTS RETAINED IN TAGGED CLUSTERS	
	July 4–6	Oct. 6–9
	Per Cent	*Per Cent*
Lead arsenate plus zinc sulfate	82.9	78.1
DDT	76.1	67.4
DDT plus zinc sulfate	77.8	68.5
Check (zinc sulfate)	64.7	56.8
Difference required for significance (P=0.01)	5.1	7.2

A significantly higher percentage of nuts was retained on the trees sprayed with lead arsenate or DDT than on the checks. Slightly but significantly more nuts were retained on trees sprayed with lead arsenate than on those sprayed with DDT. However, it is possible that the effectiveness of the DDT-pyrophyllite mixture was reduced because it did not mix well with water. Zinc sulfate did not appear to influence the effectiveness of DDT. DDT, as used, did not injure the trees.

Observations in October showed that the walnut caterpillar, *Datana integerrima* G. and R., caused light to severe defoliation in 7 of the 20 trees that had been sprayed with DDT, whereas practically no leaves were destroyed on 10 trees that had been sprayed with lead arsenate.

LABORATORY TESTS.—In July 1944, at Brownwood, Tex., groups of 38 to 60 second-growth pecan shoots were sprayed with DDT or lead arsenate to which zinc sulfate had been added at the rate of 2 pounds. The cut end of each shoot was sealed with fused *Congo*,[1] and the shoot was placed in a vial with 1 nut casebearer egg that was nearly ready to hatch. Groups of 53 to 62 untreated shoots were handled and exposed to infestation in a similar manner.The tests were replicated three times. The shoots were examined 4 or 5 days after they were sprayed, to determine the effect of the treatments on the newly hatched larvae. In the vials containing shoots treated with DDT 67 per cent of the larvae were dead, as compared with 55 per cent in the vials containing shoots treated with lead arsenate and 6 per cent in those with untreated shoots.—6-1-45.

[1]Method devised by E. H. Siegler (personal communication).

DDT Residual Spray Tests in Panama[1]

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In April 1944, while the authors were on another assignment in the Panama Canal Zone, the opportunity was presented to make some tests with DDT residual spray against adults of *Anopheles albimanus* Wied. Earlier work at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine (Gahan *et al.*, 1945) had shown that DDT residues on wood and canvas remained toxic to *A. quadrimaculatus* Say for long periods of time. The following tests are recorded because of their possible bearing on malaria control, and because they represent the first tests made with DDT residual spray in Panama.

A small, cylindrical screen-wire cage (½ sq. ft. surface) that had been treated with DDT at the rate of 200 mg. per square foot was used in a few tests on *Anopheles albimanus* to determine the speed of knock-down. Reared specimens of this species were obtained through the courtesy of the Army School of Malariology.

In the first test approximately 50 *Anopheles albimanus* 1 to 4 days old were placed in the cage, which had been treated 37 days previously. The test was conducted at a temperature of 83° F. and an estimated relative humidity of 70 per cent. One-half of the mosquitoes were knocked down in 12 minutes, and all were down in 28 minutes. Three days later the test was repeated under the same conditions with 2-day-old females only. Fifty per cent were knocked down in 18 minutes and all were dead in 26 minutes. In another test females 2 days old were exposed for 10 minutes in the treated cage and then transferred to a clean jar. All mosquitoes were down in 38 minutes.

The same cage was tested against *Anopheles quadrimaculatus* at Orlando 14 days later, at a temperature of 80° F. and a relative humidity of 78 per cent. Fifty per cent of these mosquitoes were downed in 27 minutes, and all were down in 47 minutes. Since previous work had shown that a 14-day interval does not appreciably slow up the toxic action of DDT on screen-wire cages, it is concluded that *A. albimanus* is more susceptible than *A. quadrimaculatus* to this insecticide.

To obtain information under field conditions, the interior of a jungle hospital tent (8 by 8 by 8 ft.) was sprayed with 1 quart of 5 per cent DDT in kerosene and the tent was then set up in the jungle, where it was subject to natural weathering. Observers sat inside the tent for 30 minutes, during which time approximately 50 *Mansonia* mosquitoes and a few anophelines entered. At the end of this time many mosquitoes were resting on the ceiling and walls, and several were affected by the contact with DDT. The tent was closed and after 30 minutes none of the mosquitoes were able to fly.

In this and in other tests it was observed that *Anopheles albimanus* is a cautious biter, and that the slightest movement of the host causes the insect to fly to the walls where it will sit for several minutes before again attempting to obtain a blood meal. After obtaining a blood meal it will rest on the walls for several minutes. These observations suggested that numbers of infected mosquitoes might be killed when they seek blood meals in dwellings, even though they do not habitually rest in houses. This might be accomplished by systematic spraying of native dwellings and other buildings in malarious areas.

Observations in the tent were continued over a 32-day period. In all tests the mosquitoes would enter freely, many of them landing on the walls and ceiling almost immediately. On the 24th day after treatment about 80 mosquitoes (fully ¼ of them *A. albimanus*) came into the tent in 10 minutes. The flap was closed and in 30 minutes 75 per cent of the mosquitoes were knocked down. None were up 2 hours later. On the 32nd day after treatment, the DDT appeared to be about as effective as it was when first tested.

These few preliminary tests suggest that DDT may be of great value in reducing malaria rates not only where *A. albimanus* is the principal vector, but also in many other areas where the malaria vector or vectors may be nondomestic or sylvan in habit. It is therefore urged that practical tests be made wherever possible, in order to ascertain the possibilities of DDT residual treatments against all species of malaria vectors regardless of their habits.—6-2-45.

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

[2] Now Captain, Sanitary Corps, United States Army.

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DDT for Control of the Onion Thrips

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Since the onion thrips, *Thrips tabaci* Lind., is a serious pest of onions and cotton in the lower Rio Grande Valley of Texas, especially during periods of drought, experiments for control with DDT (1-trichloro-2,2-bis(*p*-chlorophenyl) ethane) were conducted at Raymondville during April 1944.

Three series of 0.1-acre field plots, arranged in randomized blocks with four replicates in series 1 and 3 and two replicates in series 2, were used. The DDT was applied as a dust at various strengths in pyrophyllite.

One application of dust was made in series 1 and 2, and two in series 3. All the dusts were applied with single-nozzle rotary hand dust guns early in the morning, when the onions were usually damp or wet with dew and the air was fairly calm. The dosage ranged from 0.21 to 1.70 pounds of DDT per acre.

The number of adult and nymphal thrips on eight plants from each plot was determined before and after treatment by striking the tops of the plants across the black rubberized surface of a steel table and counting the dislodged insects. The population was exceedingly high, and considerable damage had been caused before treatments were begun. Yield records were not obtained, as the onions were har-

[1] The authors were assisted in the field by Ivan Shiller, O. L. Walton, C. A. Richmond, W. T. Wellhouse, and Ignacio Moreno.

[2] In cooperation with the Texas Agricultural Experiment Station.

Table 1.—Thrips infestation on onions following various treatments with dusts containing DDT in pyrophyllite.

Strength of DDT *Per Cent*	Mixture per Acre *Pounds*	Thrips per Plant[1] Before Treatment	After 24 Hours	After 96 Hours
Series 1:				
5	27	74	14	40
10	17	71	7	33
Check, no treatment	—	117	143	191
Minimum significant difference, 5% level	—	—	51	79
Series 2:				
2.5	8.5	237	87	90
	19	171	40	86
5	9	261	20	97
	19.5	199	7	75
10	9	175	10	54
	15	242	5	38
Check, no treatment	—	238	138	98
Minimum significant difference, 5% level	—	—	31	
Series 3, first application:				
5	15	142	56	
10	15.5	154	52	
Check, no treatment	—	146	112	
Minimum significant difference, 5% level	—	—	33	
Series 3, second application:[2]				
5	14.5	—	99	
10	14	—	26	
Check, no treatment	—	—	356	
Minimum significant difference, 5% level	—	—	77	

[1] Average of four plots except in series 2, average of two plots.

[2] Applied 4 days after the first.

vested soon after treatment, when about one-fourth grown, to take advantage of a favorable market.

The treatments, dosage, and number of thrips per plant are given in table 1.

There was a significant reduction in the thrips population 24 hours after dusting in all treatments. Although there was no significant difference between the 5 and 10 per cent DDT-pyrophyllite mixtures with dosages ranging from 9 to 27 pounds of the mixture per acre, the reduction in the thrips population in general was greater as the amount of DDT per acre was increased.

The results in series 1 and 2 indicate that DDT was effective for at least 96 hours after dusting, although the thrips population had increased in all treatments since the previous examination.

The results are considered sufficiently encouraging to warrant further experiments.—4-20-45.

DDT and "Control" of Honeybees

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The presence in out-of-the-way colonies of honeybees near, and in houses, is a source of annoyance, not only because of the numbers of the bees but also because of the possibility of their stinging. Bees can be particularly annoying and disturbing when they form a colony near the windows or doors of a house.

The present note concerns one such colony that had become firmly established under the trim, or millwork, of the main doorway of a house. At the time of treatment the colony was very active and had been for over a year. The total number of bees in this colony was estimated at 30,000. There were several entrances into the colony along the mortar spaces between the courses of brick underlying the trim of the doorway.

The eradication of this out-of-the-way colony presented many difficulties. Removal of the brood would have entailed considerable work in getting behind the trim. The use of cyanide or other fumigant was objectionable to the occupants of the house because of possible undesirable odors.

In order to overcome these difficulties it was decided to use DDT (dichloro-diphenyl-trichloroethene) to eradicate the colony. Wolfenbarger (1944) has already reported the successful use of DDT in the eradication of out-of-the-way colonies and notes the advantages of the residual action of DDT and its relative safety for use as regards fire hazard and the health of the occupants of the house.

In the present case two treatments with DDT were enough to eradicate the colony. In the first treatment, applied in early May, liquid and dust forms of DDT were used. The liquid DDT (2 fluid ounces of 5 per cent *Gesarol SH-5* to one quart of water) was applied to the area around the entrance holes. Before the treated area dried it was dusted with 3-per cent DDT dust. The same material was also dusted into the entrance holes. No attempt was made to block the entrance holes after treatment. Some bees, particularly drones, became incapacitated within 20 to 30 minutes after this treatment.

The second treatment was made one week after

the first. By this time the colony was seemingly not as active or as strong as it was the week before. DDT dust, 5 per cent, was used on the area about the entrance holes and about 2 ounces of the material was dusted into the entrance holes. These holes were not blocked after treatment.

Workers and drones were being knocked down within 15 minutes after treatment. Coverage of dust on the bees underneath the trim was excellent. All bees that emerged within 15 minutes after treatment were covered with the dust.

Ten days after the second treatment a few robber bees were beginning to visit the colony, which by this time had been nearly eradicated. The robbers were not using the regular entrance holes but were entering the colony, or nest, through holes that had not been treated. Within 2 weeks after the last treatment the robbing had reached a peak. Numerous robbers were emerging from the colony well covered with DDT dust. Several dead robber bees were found only a few feet from the colony. An examination of these robber bees showed that they were either heavily laden with honey or had DDT all over their wings and bodies.

One month after treatment there was no evidence of an active colony. Robber bees had cleaned out the honey thus eliminating the possibility of honey spilling on the area around the doorway and thus creating a nuisance. Five weeks after the last treatment the colony had been completely eradicated and the honey removed by robbers and no robber bees were in evidence.

The use of DDT for the eradication of honeybees in out-of-the-way colonies presents an easy and efficient way of control. However, the question arises as to the danger of poisoning and killing bees from other colonies that may come to rob a colony weakened by DDT dust application. Such robber bees may in turn help to poison desirable colonies of bees. Thus unwittingly the use of DDT for the eradication of out-of-the-way colonies may be killing hive bees. Until this has been actually determined it will probably be best to limit the use of DDT in such treatments to cases where there is no danger of affecting nearby hive bees.—7-14-45.

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Methyl Bromide for Control of the Pineapple Mealybug

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The pineapple mealybug, *Pseudococcus brevipes* (Ckll.), which is associated with pineapple wilt, is the most important insect pest of pineapples in Florida.

Practically all new pineapple plantings are propagated with suckers and slips taken from old, established plants, and in a great many cases the propagating material is infested with mealybugs. If noninfested material is used, heavy mealybug infestations do not appear so soon as if infested material is planted. Growers therefore consider it bad practice to use infested material and, in some instances, have treated infested plants before setting them in the field by dipping them in an oil emulsion or by fumigating them with hydrocyanic acid gas. Either of these methods usually fails to eliminate all the mealybugs, and both methods have caused plant injury at times.

At intervals during the past year, workers at the Subtropical Fruit Insects Laboratory in St. Lucie County, Fla., in cooperation with P. K. Platts, a grower in that county, made fumigation tests with methyl bromide for the destruction of the pineapple mealybug. The preliminary results have been so satisfactory that a brief report seems justified.

Some of the tests were carried on within a box enclosure (capacity 150 cubic feet) located in the field near the source of the stock to be treated. The box consisted of a wooden frame covered on the sides and ends with overlapping sections of tarred roofing paper; the ground served as a floor, and the top was covered during fumigation with overlapping strips of roofing paper and with two layers of tarpaulin, drawn down tightly around the sides and ends of the box. The bottom edge of the box rested in a shallow trench, and soil was thrown up around the outside to help confine the gas. The material to be fumigated was tightly packed in crates and stacked in the chamber, which had a capacity of 15 crates (1100 to 2700 plants, depending upon the size and type of material). Pineapple suckers and slips treated included Queen, Abacoxi, Abakka, and Congo varieties. The required amount of methyl bromide was measured with a commercial applicator and was admitted through copper tubing into a shallow pan in the box. A small automobile fan provided air circulation during the exposure.

The first 2 tests were performed with 2 pounds of methyl bromide per 1000 cubic feet for periods of 2 hours. In 1 test the temperature ranged from 92° to 103° F., and in the other from 74° to 77°. On samples of plants examined from both tests following treatment, 746 dead mealybugs were found but no live ones. In 3 more tests the dosage was dropped to 1 pound per 1000 cubic feet with an exposure of 2 hours. In the first of these the temperature ranged from 85° to 87°, in the second from 79° to 84°, and in the third from 82° to 88°. Samples examined following treatment showed no living mealybugs, but 234 dead ones were found. All the planting material included in these tests, with the exception of the sample plants, was set in the field soon after it was treated. The plants were examined in the spring of 1945 and were found to be normal and healthy.

Early in 1945 a 50-cubic-foot, metal-lined box especially constructed to maintain constant temperatures and to prevent the escape of the fumigant, was completed at the laboratory, and 3 tests with dosages of 0.5 pound of methyl bromide per 1000 cubic feet for 2 hours at 80° F. had been performed in it up to May 1, 1945. One crate of tightly packed suckers was used in each test. Samples for determining mealybug mortality following treatment were taken from the center of the packed crates. In these 3 tests 374 dead mealybugs and 6 live ones were found.

Although these few tests were preliminary, the data indicated that methyl bromide applied at the rate of 1 pound per 1000 cubic feet for 2 hours at 79° to 88° F. would be a successful treatment for the elimination of the pineapple mealybug in planting material, and that it would not injure the plants. Exposure to 0.5 pound for 2 hours at 80° did not cause complete mortality.

It was noted during this work that the 2-pound dosage caused 100 per cent mortality of the pineapple mite *Stigmaeus floridanus* Banks, but neither pound nor half-pound dosages were 100 per cent effective.—7-23-45.

Dusting for Cattle Lice

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Since many farmers do not have dipping vats and the application of dust by hand is a slow process, an inexpensive, rapid method of treating both large and small herds for cattle lice would be very desirable. The Dairy Department of Mississippi State College reported good results in 1944 by driving about 30 animals into a large stall and blowing a dense fog of 0.5 per cent rotenone dust over them with a hand gun or fan duster, which required only a few minutes. However, no records were made of the infestation before and after the treatment, so the value of the method was considered unproven.

In the spring of 1945 several tests were conducted, largely by the junior author, which seem to establish the value of this method of application. Calves infested with *Linognathus vituli* L. and *Bovicola bovis* L. were selected and marked for treatment by clipping a ring around three circles on each side of the body to be used in counting the lice. Each circle enclosed approximately 7 to 8 square inches. Circles were placed on the neck, R 1, L 1, just behind the foreleg, R 2, L 2, and just in front of the hip, partly on the back and partly on the flank, R 3, L 3. Counts were made with a reading glass.

Table 1.—Numbers of lice in 6 marked areas on cattle before and after treatment with 0.5 per cent rotenone dust applied by (a) rubbing by hand, (b) blowing against sides of animals and (c) dust cloud over animals.

Calf No. 1. Rubbed by hand on March 17.

DATE		R 1	R 2	R 3	L 1	L 2	L 3
March	7	2	45	41	3	28	44
	9	6	20	15	5	18	26
	11	5	22	12	1	14	21
	16	4	9	16	3	11	—[1]
	17—Treated—Right side only.						
	18	0	0	0	4	11	—
	21	0	0	0	0	7	3
	27	0	2	0	1	3	2
April	3	0	0	0	2	3	0
	10	0	0	0	2	0	0

Calf No. 2. Dust blown against right side March 17.

DATE		R 1	R 2	R 3	L 1	L 2	L 3
March	7	24	16	19	33	6	22
	9	51	30	13	30	18	21
	11	67	48	18	64	48	31
	16	41	39	44	66	39	40
	17—Treated—Right side *only* but some dust blew over on left side.						
	18	0	0	0	0	3	3
	21	0	0	0	0	1	0
	27	0	0	0	0	4	10
April	3	1	2	0	0	2	1
	10	29	2	2	14	2	0

Calf No. 3. Dust cloud over animal March 17.

DATE		R 1	R 2	R 3	L 1	L 2	L 3
March	7	70	6	62	180	26	72
	9	151	28	71	160	25	30
	11	211	46	117	205	54	87
	16	281	56	112	215	68	130
	17—Treated—Dust cloud over animal and allowed to settle.						
	18	0	4	5	0	6	0
	21	0	0	0	0	0	0
	27	0	1	0	0	1	0
April	3	6	0	0	0	2	0
	10	17	0	4	13	1	0

[1] Matted hair—no counts.

As shown in table 1 the first group of 3 calves was first examined on March 7 and seven counts (only 4 shown in table) were made before they were treated on March 17 with 0.5 per cent rotenone in a carrier of about equal parts Pyrax and double ground cream tripoli earth. Calf No. 1 was rubbed on the right side by hand, leaving the left side as a check. Calf No. 2 had the dust blown against its right side, while No. 3 was placed in a room and a fog of dust blown in until the calf was hidden. The dust was allowed to settle a few minutes before No. 3 was removed. A small plunger duster was used. Examination on March 18 showed 100 per cent kill except on No. 3

Table 2.—Effect of light applications of 0.5 per cent rotenone and 10 per cent DDT on numbers of lice in marked areas on cattle when applied by (a) blowing against sides of animals and (b) dust cloud over animals.

Calf No. 4. Dusts blown against sides April 16.

DATE		R 1	R 2	R 3	L 1	L 2	L 3
April	9	78	40	18	58	51	12
	11	76	33	11	106	37	7
	13	99	23	13	115	49	6
	16	137	23	8	131	63	5
	16—Treated—DDT on right side, rotenone on left.						
	17	5	5	4	2	4	3
	18	4	4	4	1	3	3
	20	5	6	4	3	7	1

Calf No. 5. Dust cloud of 10 per cent DDT on April 16.

DATE		R 1	R 2	R 3	L 1	L 2	L 3
April	9	52	85	9	63	121	7
	11	53	84	24	105	130	16
	13	76	57	8	153	109	12
	16	108	52	23	194	78	18
	16—Treated—DDT						
	17	103	27	15	101	24	4
	18	92	34	14	87	0	0
	20	123	16	8	94	6	5

Calf No. 6. Dust cloud of 0.5 per cent rotenone on April 16.

DATE		R 1	R 2	R 3	L 1	L 2	L 3
April	9	144	80	27	81	67	21
	11	172	81	23	91	72	32
	13	210	85	19	121	95	41
	16	198	91	50	131	64	39
	16—Treated—Rotenone						
	17	54	5	10	3	3	2
	18	18	0	6	2	1	2
	20	8	8	5	3	1	0

and these were probably dead as there were no lice left in the circles on March 19. Some of the dust blew over on the left side of calf No. 2 and gave almost a complete kill on the entire body of this calf. Calf No. 3 was the only one with lice under the brisket before dusting and evidently the dust did not penetrate this long, thick hair under the body as the lice there were alive after the dusting.

A second group of three calves, Nos. 4, 5 and 6, marked as in the first group was dusted on April 16 after four infestation records were secured. Calf No. 4 had 10 per cent DDT (*Neocid A-10*) blown against its right side and 0.5 per cent rotenone against the left side, using a small plunger duster from a distance of about 3 feet in each case. A double layer of denim was held along the median line of the back to prevent the dusts reaching the opposite side. Calf No. 5 had 10 per cent DDT blown over it from about 5 feet away and calf No. 6 had 0.5 per cent rotenone from about 6 feet. All applications were light and the kill as shown in table 2 was not satisfactory, especially for the DDT. However, nearly all

the lice left on No. 5 were *Linognathus vituli*, so it is possible that DDT may be more toxic to *Bovicola bovis* than to the long-nosed louse, although the percentage of each on the animals prior to treatment was not determined. The light application of rotenone was sufficient to reduce the population in the circles on No. 6 from 573 to 25, or 95 per cent within three days as compared to a 47 per cent reduction by the DDT in the same time.

Table 3.—Effect of heavy applications of 0.5 per cent rotenone and 10 per cent DDT on numbers of lice in marked areas on cattle when applied by (a) blowing against sides of animals and (b) dust cloud over animals.

Calf No. 7. Rotenone blown against sides April 26.

Date		R 1	R 2	R 3	L 1	L 2	L 3
April	24	26	6	4	28	7	6
	25	31	4	7	30	8	9
	26	24	4	5	29	2	5
	26—Treated						
	27	0	0	0	0	0	0
	30	0	0	0	0	0	0
May	1	0	0	0	0	0	0

Calf No. 8. DDT blown against sides April 26.

Date		R 1	R 2	R 3	L 1	L 2	L 3
April	24	14	6	6	25	5	5
	25	15	5	5	29	2	5
	26	18	5	3	26	3	4
	26—Treated						
	27	0	0	0	0	0	0
	30	0	0	0	0	0	0
May	1	0	0	0	0	0	0

Calf No. 9. Rotenone dust cloud blown over animal April 26.

Date		R 1	R 2	R 3	L 1	L 2	L 3
April	24	171	46	80	98	33	82
	25	173	34	75	119	38	94
	26	174	37	74	122	74	68
	26—Treated						
	27	14	16	0	12	23	0
	30	4	1	0	5	3	0
May	1	3	0	0	2	3	0

Calf No. 10. DDT dust cloud blown over animal April 26.

Date		R 1	R 2	R 3	L 1	L 2	L 3
April	24	49	6	12	24	8	9
	25	53	5	8	22	4	7
	26	44	3	17	27	8	4
	26—Treated						
	27	0	0	1	0	0	0
	30	0	0	0	0	0	0
May	1	0	0	0	0	0	0

Four calves, Nos. 7, 8, 9 and 10, were used in a third test with heavier applications of 10 per cent DDT and 0.5 per cent rotenone, each blown directly against an animal and also by blowing a fog of dust into the air over the animals. Three counts were made before and three after dusting. The dusts were blown against the sides of the animals from a distance of about 3 feet and over them from about 6 feet. The fog was not dense enough to hide the animals but all of them had a dusty color. The results are shown in table 3. A few lice survived in the long hair under the brisket on the animals treated by blowing the dusts over them.

CONCLUSIONS.—Small plunger and fan dusters are effective means for rapid and economical application of rotenone and DDT dusts to dairy cattle infested with *Linognathus vituli* and *Bovicola bovis*. The dusts seem to be more effective when blown directly against the animals, but fog applications over them heavy enough to give the coat a dusty appearance are also satisfactory. If the latter method is used, some dust should be blown under the animals to reach the brisket and other long-haired areas. Dust containing 0.5 per cent rotenone seems somewhat more effective than 10 per cent DDT. Two applications should give almost perfect control. The value of the method on long-haired beef animals is not known.—7-28-45.

DDT for the Control of Goat Lice

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The Angora goat industry in the United States is confined largely to the Edwards Plateau of southwestern Texas, and a relatively small section adjacent to it. Ranchmen in this area consider goat lice to be the most serious insect parasite of goats. Their attack lowers the vitality of the animals and reduces the quality and quantity of mohair. Quality mohair has become of greater importance with the general adoption of grades for this product. The mohair from lousy goats is often matted and discolored, and therefore grades much lower than that from louse free animals. Much hair is also lost as a result of the goats rubbing themselves to relieve the irritation caused by lice.

There is an ever-increasing demand for a dip that will control lice on either freshly-sheared or long-haired goats in one dipping. The dipping of animals immediately after shearing would eliminate the laborious task of rounding them up a second time. In the past this procedure has been impractical because the available dips did not control the lice on freshly-sheared goats.

Laboratory and preliminary field tests made at the Menard, Tex., laboratory indicate that progress has been made in developing a dip that will control in one dipping, the three species of lice commonly found on goats. These species are the yellow louse, *Trichodectes hermsi* Kellogg and Nakayama; the red louse, *T. caprae* Gurlt; and the blue louse, *Linognathus stenopsis* (Burm.). The tests also indicate that the dip is effective on freshly-sheared goats, as well as on those with long fleece.

EXPERIMENTAL DATA.—Early tests (Babcock 1944) at this laboratory on the efficiency of DDT (1-trichloro-2,2-bis(*p*-chlorophenyl)ethane) for the control of goat lice proved its efficacy in killing lice in one dipping. A dip containing 0.2 per cent of DDT killed all three species. The solvents used in this work, however, cannot be recommended because of their cost and unavailability. Soluble pine oil, a pine oil conforming to Navy specifications, CS69–38, and containing an emulsifier, is an excellent solvent for DDT as well as an efficient wetting agent in goat louse dips. A stock solution, designated as No. 1235, was made by dissolving 1 part of DDT in 5 parts (by weight) of soluble pine oil. This stock solution is stable at ordinary temperatures. At temperatures below freezing a small quantity of the DDT may separate, but it readily redissolves at ordinary room temperature.

In a field test 927 goats that were heavily infested with red, yellow, and blue lice were dipped on July 4, 1944. At that time the goats were carrying a 5-month growth of hair. These goats were sheared 38 days after dipping. An examination at the time of shearing showed them to be free of lice. In another test 625 goats that were infested with red and yellow

lice were dipped on October 26. An examination at shearing time, March 7, 1945, showed them to be free of lice. In a third test, which was started August 15, 1944, 940 goats were dipped immediately following shearing. When the animals were examined 71 days after dipping, no lice were found. Later, because of uncontrollable conditions, these animals mingled with infested animals. At shearing time, February 15, 1945, practically all the goats had a few lice on them. However, the infestations were not sufficiently heavy to injure either the animals or their hair.

There have been no undesirable effects on either the animals or the mohair following the use of this dip. On animals that have been dipped the mohair is glossy all the way to the skin, which is smooth and without dandruff. Several animals dipped in this material have been exhibited at goat shows and have been awarded high honors.

At present prices (1945), dip made from solution No. 1235 costs between $25 and $30 per thousand gallons. This price is not prohibitive, since only one dipping is necessary. On an average 0.5 gallon of dip per animal is required when goats are in full fleece, but when goats are dipped immediately after being shorn only 0.19 gallon of dip is needed per animal. Tests show that dip kept in an open vat remains effective for 99 days or longer.

We have experimented with a dip containing approximately 0.2 per cent of DDT by using 10 pints of stock solution No. 1235 in 100 gallons of water. The dip was well stirred before use. The stock solution does not make a good emulsion in alkaline or extremely hard water. It is therefore desirable to test the water prior to dipping and to use some that will combine satisfactorily with the stock. The excellent wetting quality of stock solution No. 1235 makes it possible to wet an animal thoroughly in a single dipping.

SUMMARY.—Preliminary laboratory and field tests indicate that the three species of goat lice—*Trichodectes hermsi* Kellogg & Nakayama, *T. caprae* Gurlt, and *Linognathus stenopsis* (Burm.)—commonly found on goats in Texas can be controlled with a dip containing 0.2 per cent of DDT. This dip was prepared by diluting 10 pints of stock solution consisting of 1 part of DDT in 5 parts (by weight) of soluble pine oil in 100 gallons of water.—7-27-45.

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Mosquitoes of Northwest Florida

G. A. EDWARDS[1] and E. V. PORTER[1]

Collections of mosquitoes in the vicinity of Valparaiso, Florida, have been made for the past two years and are still in progress. This paper contains some data on the frequency and distribution of adult mosquitoes in this area for the period May 1943 to June 1945 inclusive.

Valparaiso is located in the northwestern part of the state, between Alabama and the Gulf of Mexico. The area in general may be described as a pine barren. The soil is mostly sandy, and the trees are predominantly oak and pine. There are few grassy fields, but the vegetation is fairly dense. Several large ponds, some brackish water bayous and many small bogs occur in the area.

Adult collections were made daily from New Jersey type light traps and from resting stations. Collections of larvae were also accomplished but these data will not be included in the present report. Light traps were set out near buildings, near bayous, and in the fields and woods. Resting stations were maintained near buildings, bayous, ponds and woods. The specimens collected were identified at the laboratories of the Fourth Service Command, Atlanta, Georgia.

Table 1.—Mosquitoes collected at Valparaiso, Florida, from May 1943 through May 1945.

SPECIES	NUMBER AND RANK May 1943–June 1944		NUMBER AND RANK June 1944–June 1945	
Aëdes vexans	2149	(1)	361	(4)
Aëdes mitchellae	274	(2)	859	(2)
Culex quinquefasciatus	217	(3)	782	(3)
Psorophora confinnis	147	(4)	65	(9)
Melanoconion	116	(5)	1033	(1)
Culex (Cul) spp.	115		67	
Aëdes spp.	88		116	
Culex salinarius	54	(6)	87	(7)
Uranotaenia sapphirina	49	(7)	65	(9)
Uranotaenia lowii	47	(8)	1	(25)
Anopheles crucians	28	(9)	331	(5)
Culex pilosus[1]	(23)		(297)	
Aëdes sollicitans	17	(10)	61	(10)
Culex nigripalpus	15	(11)	109	(6)
Culiseta inornata	12	(12)	9	(18)
Aëdes taeniorhynchus	10	(13)	9	(18)
Aëdes tormentor	10	(13)	20	(15)
Anopheles quadrimaculatus	8	(14)	9	(18)
Mansonia perturbans	8	(14)	23	(14)
Anopheles atropos	6	(15)	1	(25)
Aëdes atlanticus	5	(16)	54	(12)
Culex restuans	5	(16)	16	(16)
Psorophora discolor	2	(17)	0	
Anopheles bradleyi	1	(18)	5	(21)
Culex erraticus[1]	(1)		(12)	
Anopheles punctipennis	0		10	(17)
Aëdes aegypti	0		1	(25)
Aëdes canadensis	0		7	(19)
Aëdes dupreei	0		3	(23)
Aëdes infirmatus	0		4	(22)
Aëdes sticticus	0		1	(25)
Culiseta melanura	0		57	(11)
Culex apicalis	0		36	(13)
Culex peccator	0		6	(20)
Culex tarsalis	0		1	(25)
Psorophora ciliata	0		2	(24)
	3383		4201	

[1] Included under *Melanoconion* for determination of absolute rank.

There was a definite correlation between the weather and the incidence of mosquitoes. In 1943 and 1944 the hot and rainy weather began in April giving rise to the appearance of a large number of mosquitoes in late April and May. In 1945 a "false spring" occurred, that is, February was warm and wet but March and April were cool and dry. Hence mosquitoes that in previous years had appeared in April and May were recorded in February and March 1945 (Fig. 1). The number of individuals caught varied with the wind direction, that is there was a reduction in number with an onshore breeze and an increase with an offshore breeze. Normal variations in the rather steady surface winds in this area produced little change in population. During the two weeks in which hurricane winds passed through the area the number of individuals caught dropped to practically zero. Throughout the 6-week period from the middle of April to the end of May

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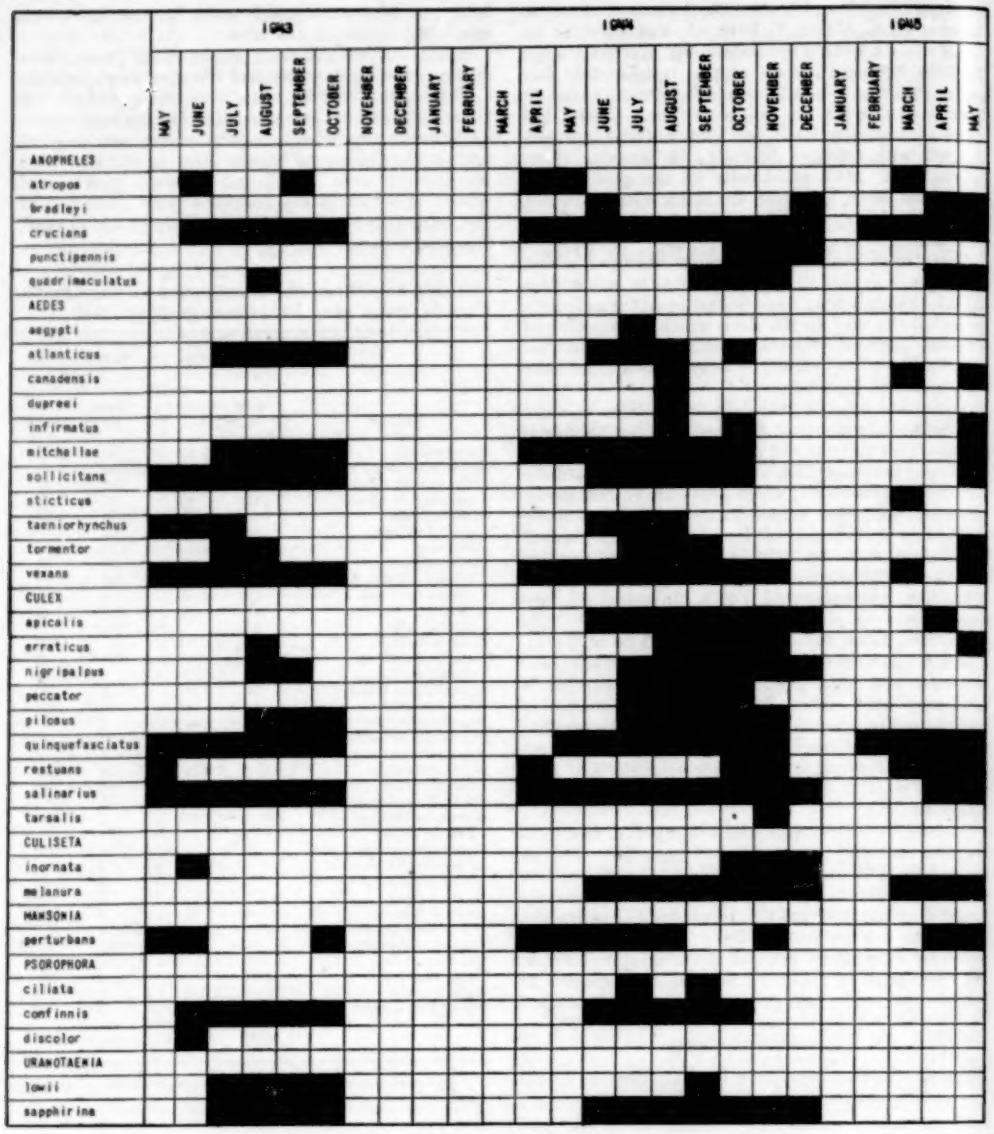

FIG. 1.—Seasonal distribution of mosquitoes in Valparaiso, Florida.

1945 there was only one short rainstorm, and collections amounted to no more than a few specimens per week.

The total number of species recorded was 33. The aggregate of adults caught between May 1943 and June 1944 was 3383; and from June 1, 1944, through May, 1945, the total collection of adults was 4201. Of the specimens collected in 1943–44, 91.7 per cent were females and only 8.3 per cent males. During 1944–45 the number of females collected equalled 68.3% of the total and the males 31.7 per cent. The number of specimens collected and the rank of their importance is given in table 1.

All species represented in the collection have been previously reported for the state of Florida (King *et al.*, 1944). The species collected and their order of abundance were, in general, similar to those reported from Tampa, Florida (Dethier & Whitley 1944). The following species reported by Dethier & Whitley for Tampa were not present in the collections at Valparaiso: *Mansonia titillans* and *Psorophora ferox*. Conversely those found at Valparaiso but not reported from Tampa were: *Aëdes dupreei, A. sticticus, A. tormentor, Anopheles punctipennis, A. bradleyi, Culex peccator, C. tarsalis* and *Psorophora discolor*. In the order of their relative abundance the species from the two sections of the state were similar. In 1943 and 1944 the most prominent species at Valparaiso was *Aëdes vexans*. Following in abundance were *A. mitchellae, Culex quinquefasciatus, Psorophora confinnis, Melanoconion, C. salinarius* and *Uranotaenia sapphirina*. *Melanoconion* rose to first

place in 1944 and 1945, followed in order by *Aëdes mitchellae, C. quinquefasciatus, Aëdes vexans, Anopheles crucians, C. nigripalpus* and *C. salinarius.*

From the chart (Fig. 1) it can be seen that many variations as well as similarities in distribution occurred during the 2-year period. Ten species appeared in 1944 that had not been found in 1943. *Aëdes sticticus* was collected for the first time in 1945. *Psorophora discolor* appeared only in 1943. The males of *Culiseta melanura, Melanoconion, Culex apicalis and C. nigripalpus* occurred in the collections only in late fall and early spring, whereas the females were present spring, summer and fall. Males only were found of *Culex peccator.* Females only of the following were collected: *Anopheles atropos, A. bradleyi, A. quadrimaculatus, Aëdes dupreei, A. sticticus, A. tormentor* and *Culiseta inornata.*—7-27-45.

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DDT for the Tent Caterpillar

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The tent caterpillar, *Malacosoma americana* (Fab.) was abundant during the spring of 1945 in Conn., apparently near the peak of one of its cycles. DDT supplied by the Geigy Company was tested against this insect in the laboratory and out-of-doors.

The first test was of *Gesarol Summer Oil* spray applied to a tent by a medicine dropper. This penetrated the tent well and immediately affected the caterpillars which became partially paralyzed. All were dead in two days.

Another tent was sprayed with about 1.7 cc. of *Gesarol Summer Oil* spray. Within three minutes the caterpillars started to leave the tent and at the end of 10 minutes all were quiet. Later many were twisting and squirming but were unable to crawl. The next day all were dead and greatly shrunken in size.

Twenty-five larvae, about one inch each, were brought into the laboratory and placed on the tent used in the previous test two days after it was sprayed. Within 10 minutes several had left or spun down from the tent. These were placed in a clean cage. The only contact they had had with DDT was by walking for a short time on the sprayed tent. The next morning about half were dead while the rest could move only slightly. All were dead on the second day.

To test the effect of treating the tent when the larvae were out feeding, a tent was sprayed with about 1.7 cc. of *Gesarol Summer Oil* spray taking care not to hit the feeding larvae or the silken trails with the spray. This treatment upset the normal activities of the colony. Feeding stopped very soon and a few caterpillars returned to their tent but none entered. These soon left the tent by crawling or spinning down. It was noticeable that those crawling did not follow the trails as is their normal custom but moved rapidly over any nearby surface. Some of the larvae dropped from the foliage and did not attempt to return to the tent. It is possible that some of the very fine spray mist reached these larvae. All of the caterpillars became paralyzed and later died although two continued to move slightly for three days.

A group of 22 large larvae on a tent was sprayed with 3.4 cc. of spray made by mixing 0.1 cc. of *Gesarol Emulsion* with 100 cc. of water. They began to drop within five minutes and all had left the tent in 15 minutes. These became partially paralyzed but were able to squirm more or less for several hours. The next day all were dead except one which died on the following day.

After these preliminaries in the laboratory, three groups of tents along roadsides were treated. Fourteen tents were sprayed on a very windy day with the temperature at 54° F. Most of the caterpillars were at home within the tents but some were grouped outside. Twenty-five cc. of *Gesarol Summer Oil* spray were sprayed on these tents, the amount varying from 0.72 to 3.6 cc. according to the size of tent. The spray was applied by a cheap household sprayer. Checks later failed to find any live caterpillars in these tents.

Another lot of 10 tents was sprayed with 10 cc. of *Gesarol Summer Oil* spray. The range per tent was from 0.32 to 2.4 cc. These caterpillars averaged about one inch long and many of them were out of the tents feeding at the time of spraying.

On the same day nine tents were treated by shaking a small amount of *Gesarol A3* dust on each. The smallest tent received 0.35 grams and the largest received 1.05 grams.

A later examination failed to find any live larvae in or near any of these tents.

From these preliminary experiments it appears that DDT is deadly to tent caterpillars by contact even when greatly diluted. The caterpillars stop feeding immediately, become paralyzed and later die. The results are the same when larvae crawl on a tent or other surface which has been sprayed or dusted with DDT.—7-25-45.

Soil Nitrogen and Thrips Injury on Spinach[1]

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Information on soil-plant relations as factors in insect control is insufficient. But that the nutritive qualities of agricultural crops are influenced by the fertility of the soil on which they are grown is a well established fact. Furthermore, it has been occasionally suggested by students of entomology that the ability of plants to resist insect attack may be modified by controlling their mineral nutrient supply. Some of the possibilities in this, as yet, little known and practically unexplored field of pest control have recently been suggested in our nutritional studies with vegetables. A striking relationship was observed between the amounts of soil nitrogen and calcium provided for plants of New Zealand spinach, *Tetragonia expansa,* and their resistance to attack by the common greenhouse thrips, *Heliothrips haemorrhoidalis.*

The test plants were grown under controlled conditions in gallon glazed crocks using clay-sand cultures. A series of sixteen treatments was prepared by supplying calcium and nitrogen levels each of 5, 10, 20, and 40 milliequivalents per crock with all possible (i.e. 16) combinations in these amounts of the

[1] Missouri College of Agriculture, Journal Series No. 988.

Table 1.—Variations in yield, vitamin C, oxalate, and mineral content as related to the incidence of thrips injury on New Zealand spinach grown at variable levels of nitrogen and calcium.[1]

Treatment	Applied N	Applied Ca	Yield per 10 Plants	Vitamin C per 100 Gm.	Oxalate	Mineral Analyses N	PO_4	Ca	Mg	Leaf Surface Damaged
	m.e.	*m.e.*	*gm.*	*mgm.*	%	%	%	%	%	%
					N group I					
1	40	40	467.6	20.3±0.70	6.07	6.12	1.63	0.460	0.554	8.0
5	40	20	280.0	18.9±0.98	5.80	5.97	1.65	0.659	0.164	0.0
9	40	10	461.2	21.4±1.01	6.05	6.07	1.73	0.456	0.262	3.8
13	40	5	466.2	22.8±0.66	6.17	6.18	1.67	0.548	0.041	2.5
Average			418.8	20.9±0.48	6.02	6.09	1.67	0.531	0.255	3.6
					N group II					
2	20	40	422.2	28.5±0.87	7.08	4.79	2.34	0.536	0.393	12.4
6	20	20	367.7	27.9±1.18	7.42	5.25	2.21	0.479	0.086	10.3
10	20	10	325.1	25.3±1.54	7.13	5.60	1.78	0.602	0.337	1.3
14	20	5	392.1	26.9±1.06	6.86	5.76	2.06	0.528	0.025	3.4
Average			376.8	27.2±0.59	7.12	5.35	2.10	0.536	0.211	6.9
					N group III					
3	10	40	267.7	29.5±0.63	7.95	3.58	3.68	0.570	0.343	10.0
7	10	20	230.8	28.7±0.74	7.52	4.64	2.97	0.548	0.069	44.5
11	10	10	219.4	29.5±0.57	7.24	4.76	2.52	0.520	0.389	52.5
15	10	5	158.5	30.5±1.38	6.77	5.06	3.25	0.506	0.074	51.0
Average			219.1	29.6±0.44	7.37	4.51	3.11	0.536	0.219	39.5
					N group IV					
4	5	40	142.2	27.0±0.72	9.36	3.06	3.63	0.618	0.368	17.8
8	5	20	122.8	28.4±1.02	7.34	3.33	4.00	0.634	0.340	45.0
12	5	10	121.5	30.0±1.16	8.57	3.84	3.56	0.583	0.131	45.0
16	5	5	98.8	29.6±0.80	7.42	3.82	4.40	0.514	0.324	46.5
Average			121.3	28.7±0.49	8.17	3.51	3.90	0.587	0.291	38.6

[1] Yield given in fresh weight per 10 plants, vitamin C in milligrams per 100 gms. fresh weight, oxalate and mineral analyses in percentage of dry weight.

two nutrients. Each series was replicated ten times with two plants in each replication. Calcium acetate and ammonium nitrate were the respective sources of the variable elements and all other nutrients were provided in constant amounts for all treatments. The plants were randomized in a greenhouse infested with thrips, the insects being left free to choose whatever plants they wished.

During the first 6 weeks growth, of the 320 plants in the experiment, not one of the 160 plants grown at the two higher nitrogen levels was seriously attacked by the insect. This condition was in sharp contrast to that observed on an equal number of plants grown at the two lower nitrogen levels, of which practically all were badly damaged. It was also of significance that when the calcium supply was increased the attacks on the low nitrogen groups were less serious.

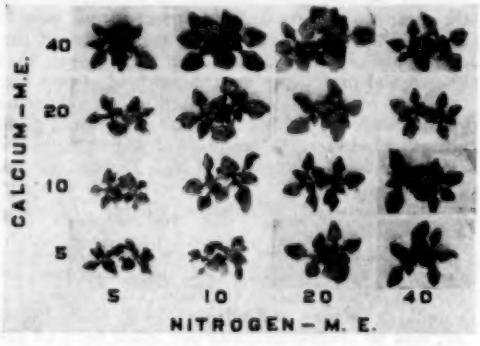

FIG. 1.—Thrips injury on New Zealand spinach grown at variable levels of calcium and nitrogen.

The insects' preferential selection of the plants according to the nutrient level of the substrate is illustrated by the pictorial graph (Fig. 1) in which representative specimens from each treatment are portrayed. As shown, thrips injury was almost absent at the two higher nitrogen levels, and at the highest of the calcium levels.

Because of the well known effects of nitrogen and calcium on the growth and composition of leafy vegetables, a relationship between soil fertility and the production of plants resistant to or unsuitable as food for insect pests seemed likely, and prompted some detailed chemical analyses of the plants in the various treatments. These results with the percentages of leaf surface damaged are given in table 1. In general, the plants selected for food by the thrips made less total growth and were higher in vitamin C, oxalate, and phosphorus, and lower in total nitrogen. The predominating influence of the nitrogen increments on growth, chemical composition, and incidence of insect damage was obvious.

For a proper interpretation of these observations and data, one should be mindful of the following items of interest: (a) most insects have specific hosts, signifying, perhaps, that they have definite food requirements to satisfy; (b) the nutrient contribution of the host plant may be altered tremendously by soil fertility, especially, as in this case, when the nitrogen is varied; (c) the long recognized value of crop rotation in pest control may be, in

part, a result of better maintenance of soil fertility and consequent greater "plant resistance"; (d) the explanation as to why some crop pests, such as codling moth, become more serious as fruit trees are grown continuously in the same soil without a complete renewal of the nutrients removed, may be found, in part at least, in soil deficiency; and (e) possibly, the continuing need for the creation of new insecticides to hold in check greater and more destructive ravages of insect pests is aggravated by the gradual but general decline in soil fertility from year to year.—8-13-45.

Sorption of HCN by Insect Pupae

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The toxicity of an insect fumigant is a function of many variables. It depends to a considerable extent on the chemical constitution of the compound and its physical and chemical properties in the gaseous phase. The temperature and relative humidity affect both the fumigant and insect in varying degrees. The physiology of the insect at different stages of development influences greatly the toxicity of a fumigant. Even when two species of insects sorb the same amount of fumigant under identical conditions, the lethal dosage for each species may be very different. Aside from the variation in tolerance of insects to a given fumigant, all of these factors, therefore, bear a definite relation to the sorption of the fumigant by the insect during the period of exposure. In an effort to determine the basis for the difference in sorption of fumigants HCN was chosen as a suitable gas for use in studying the physical, chemical, and physiological factors affecting its sorption by various insects during fumigation. As part of the general project, this paper reports the results of experiments on the relative amounts of HCN sorbed by pupae of the housefly, *Musca domestica* L., of different ages.

Previous experiments (Lindgren and Sinclair 1944) with pupae of the walnut husk fly, *Rhagoletis completa* Cress., have shown that very much more HCN was recovered from those fumigated at low relative humidities (15 to 20 per cent) than from those fumigated at high relative humidities (70 to 90 per cent). It was also shown that less HCN was recovered from fumigated husk-fly pupae than from fumigated red scale, and that red scale is more susceptible to HCN fumigation. Age of the husk-fly pupae was not considered in these earlier experiments, since the husk-fly remains in the pupal stage for the better part of a year, and the experiments reported on were carried out over a period of a few days.

Since housefly pupae[1] were available in large numbers, an experiment was set up to determine the amount of HCN that might be recovered from pupae of various ages. The houseflies were reared in the laboratory under controlled conditions, and the age of the pupae was known to within 12 hours. A large number of pupae having been obtained, samples from this single source were fumigated daily, and the HCN was recovered immediately after fumigation. The housefly pupae were fumigated with 16.8 mg. HCN per liter, at 75° F. and an exposure of 40 minutes. The relative humidity varied from 48 to 78 per cent, this range in variation having little or no effect on the amount of HCN recovered from the pupae. Methods of HCN recovery were similar to those worked out by Sinclair & Ramsey (1944).

The results of these experiments are shown in figure 1. It may readily be observed from the graph that the amount of HCN recovered per gram of pupae varies with the age of the pupae. There is a definite decrease in the amount of HCN recovered from pupae 1 to 3 days old, with about the same amount recovered from those 3 to 5 days old, and a progressively greater amount recovered from those 5 to 8 days old, at which time the adults were about to emerge.

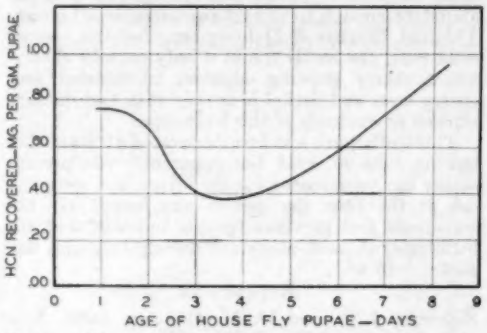

FIG. 1.—Recovery of HCN from fumigated housefly pupae of different ages.

The trend of this curve follows in general the trend of the mortality curve obtained by Lindgren (1935) with a given concentration of chloropicrin on pupae of *Tribolium confusum* of different ages. He found that the pupae were least resistant to the fumigant at the beginning and at the end of the pupal stage, and most resistant from the second to the fourth day. No attempt is being made to formulate a generalization, but the authors were impressed by the similarity of the mortality curve of pupae of *Tribolium confusum* and the HCN sorptive curve of the housefly pupae.—8-27-45.

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[1] The authors are grateful to Dr. Paul de Bach for supplying the housefly pupae used in these experiments.

A New Leafhopper on Cherry

S. W. FROST, *Pennsylvania State College*

Cicadella stellulata (Burm.)[1] has been found on sour cherry at State College, Pa. This is apparently an introduced species which previously has been reported only from New Haven, Connecticut under the name *Typhlocyba inscripta* Sanders & DeLong

[1] Material determined by Mrs. J. N. Knull.

(1922). The species was described at that time from 11 females collected at Kew Gardens, London, England and seven males from New Haven, Connecticut. Virtually the same information appears in The Hemiptera of Connecticut (1923). No mention of this species could be found in DeLong & Caldwell (1927).

This is a pretty species that can readily be distinguished from other leafhoppers attacking fruit. It is almost entirely chalky white with pale brown eyes and scutellum and with brown and black blotches and delicate lines on the outer halves of the wings.

The nymphs and adults produce white stippling upon the leaves of sour cherry, the injury being abundant enough to attract considerable attention. Although Sanders & DeLong recorded this species from pear, the writer found it only on sour cherry. Sweet cherry growing adjacent to infested sour cherry trees and Seckel pear only fifty feet distant, showed no evidence of this leafhopper.

This leafhopper was first discovered at State College on June 20, 1945 but apparently was present earlier the same season for the injury was conspicuous at the time the species was found. My observations and previous records indicate that the leafhopper is most abundant during July and August.—7-25-45.

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DDT-Like Effects from Injection of Other Compounds into Roaches

SAM C. MUNSON and J. FRANKLIN YEAGER,
U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine

In several semiquantitative exploratory experiments molar concentrations of DDT (1-trichloro-2,2-bis(*p*-chlorophenyl)ethane; m.p. 108.5–109° C.) and a number of other compounds were injected into nymphs of the roach, *Periplaneta americana* (L.). These compounds were compared with DDT with respect to symptoms produced and to speed of kill of the most effective doses. The results, which are to be considered as only approximations, are summarized in the numbered paragraphs. The number after the name of a compound was obtained by dividing the survival time for the most effective dose of the compound into the survival time of a corresponding dose of DDT. This number serves as an approximate index of the speed of kill of the compound relative to that of DDT. Compounds that exceeded DDT in speed of kill have an index greater than unity. The compounds in group (1) caused symptoms that at some stage were practically indistinguishable from some stage of DDT symptoms.

(1) Symptoms very similar to those caused by DDT: *p*-Dichlorobenzene 1.08; hydroquinone 4.88 (in 1.1 per cent sodium chloride), 1.07 (in corn oil); aniline 1.91: phenol 1.47.

(2) Symptoms only moderately like those caused by DDT: Diphenylamine 1.52; benzene ca. 0.50.

(3) Symptoms not like those caused by DDT: *o*-Chlorodiphenyl 0.13; bibenzyl 0.46; *p*-nitrophenol 3.30; toluene 0.10; benzoic acid 0.68; salicylic acid 0.35; xylene 0.12; phenothiazine 8.63.

(4) Intermediate between groups (1) and (2): Pyrogallol (in 1.1 per cent sodium chloride) 1.13; *p*-phenylenediamine 1.20; alpha-naphthol 0.49; dimethyl-*p*-phenylenediamine 1.24; tetrachlorohydroquinone 4.46 to 6.24.

(5) Intermediate between groups (2) and (3): Chloral hydrate 0.74; biphenyl 0.51; tetrachlorobenzene 0.87.

The DDT symptoms involved initial increase and subsequent decrease of general activity, spasmodic contractions, twitches, tremors, and loss of equilibrium and locomotion. Comparison was based upon all symptoms, but especially on the characteristic contractions, twitches, and tremors. The values for speed of kill show that benzene was less effective than DDT, but that a benzene ring with Cl, OH, or NH_2 substituted in the para position could be as effective as, or more effective than, DDT. The results are in agreement with the idea expressed by Läuger *et al.* (1944), that the DDT molecule consists essentially of a toxic (aromatic) portion chemically combined with a carrier (chloral) portion, the latter being considered chiefly responsible for the penetration properties of the molecule.

Rough estimates of minimum lethal doses for the more toxic compounds were made from the data; in general, these doses seemed to be greater for compounds that had higher water solubility, suggesting that the more water-soluble compounds might be excreted more readily than the others.

Some of the compounds are known to be oxidized by the cytochrome enzyme system, and three of these (the first three in group (4)) long have been used in the histochemical detection of indophenol (cytochrome) oxidase. These facts, together with the results given above, suggest that an effect upon the cytochrome oxidase system in the insect might be a part of the mode of action of DDT.—7-25-45.

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The Toxic Gases of Lime-Sulfur

CYRIL E. ABBOTT

When ordinary air is passed through a solution of lime-sulfur, free sulfur is precipitated and gases are evolved. The gases are distinctly toxic to insects. This toxicity has generally been attributed to the presence of sulfur dioxide, but it has always seemed to me that insecticidal action depends primarily upon the presence of hydrogen sulfide. To judge from the evidence afforded by the human olfactory organ hydrogen sulfide is generated in far greater quantity than sulfur dioxide. Furthermore, although both gases are strong reducing agents, hydrogen sulfide is chemically the more active of the two. Finally, tests of the comparative toxicity of the two gases give results which indicate that hydrogen sulfide is more toxic than sulfur dioxide.

By way of illustrating my last point, an example may be described here. Figure 1 illustrates the effect of each of the two gases upon the heart rate of speci-

mens of *Passalus cornutus*. Each specimen, with the elytra removed, was exposed to a flow of concentrated gas in a transparent chamber, and the heart action observed by means of a binocular magnifier. Time intervals were determined by means of a stopwatch. Since the dorsal abdominal wall of *Passalus* is quite transparent, observations of heart action are easily made. The results indicate that hydrogen sulfide is much more toxic than sulfur dioxide. Similar results were obtained in testing the immobilization of *Polistes fuscatus*.

The chemistry of calcium polysulfides is very complex, but is sufficiently familiar to entomologists to preclude the necessity of further discussion at this point. An excellent review of the subject has been published recently by Frear (1942). Although now rather old, the paper by Debus (1888) is worthy of consideration. Others of interest have been published by Wilcoxen & McCallan (1930), Goodwin & Martin (1928, 1929), and Liming (1930). None of these papers discusses at length the possible action of carbon dioxide upon lime-sulfur, although Frear mentions the fact that carbon dioxide decomposes the material.

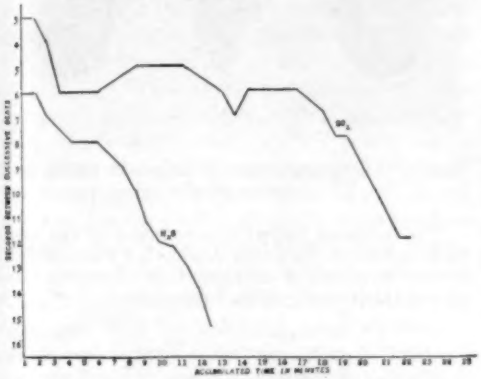

FIG. 1.—Relative toxicity of SO_2 and H_2S as indicated by their effects on the heart of *Passalus cornutus*

When air freed of carbon dioxide is passed through solutions of lime-sulfur the decomposition of the latter requires hours or even days. Yet air containing small quantities of carbon dioxide decomposes the material completely in less than two hours, and a mixture of equal parts of air and carbon dioxide will do so in little more than half an hour. Decomposition results in the formation of the products already mentioned and a number of salts which remain in solution: the latter probably consist of calcium sulfite, calcium thiosulfate, and the polythionates of calcium.

A technique was devised to determine the relative quantities of hydrogen sulfide and sulfur dioxide generated by the decomposition of the lime-sulfur. An ordinary, small, gas generator, such as those assembled by students in beginning chemistry, supplied the carbon dioxide. To it was attached an air pump which delivered a liter of air per minute. The mixture of gases from the air pump and generator were then conducted into a 500 cc. container which held the lime-sulfur solution. By means of stopcocks and a manometer the flow of gases was kept reasonably constant. The gases which came from the lime-sulfur were collected, at successive, equal intervals, in numbered test tubes, each of which contained 10 cc. of M/2 silver nitrate solution. It is comparatively easy to separate the resulting sulfide from the sulfite of silver, since the latter is soluble in ammonium hydroxide while the former is not. The lime-sulfur solution contained about 0.1 gm. of polysulfides per ml.

The precipitate formed was collected on filter paper, washed with water, and then with ammonium hydroxide, the latter being collected and evaporated. Upon partial evaporation, a precipitate of silver sulfite formed and was collected on filter paper.

The samples were dried and weighed. They constituted two series: one consisting of silver sulfide collected at intervals of about 3 minutes throughout the decomposition of the lime-sulfur, and the other of silver sulfite samples collected at the same intervals. Hence the former represented the approximate quantities of hydrogen sulfide generated; the latter the quantities of sulfur dioxide.

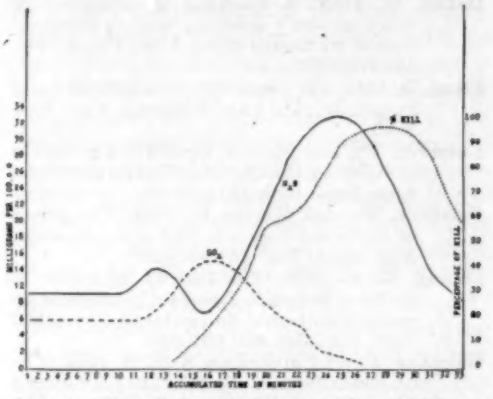

FIG. 2.—The relationship between SO_2 and H_2S generated from calcium polysulphides and their relation to insect mortality.

A test was also made to determine the lethal power of the combined gases during different periods of their generation. Using the apparatus already described, the gases were conducted into a series of containers, each of 800 cc. capacity, and each containing 50 adult specimens of *Lucilia sericata*. The containers, after an exposure of 3 minutes each to the gases, were left open until some of the flies became active: they were then loosely plugged with cotton and left for 24 hours. At the end of that period the dead flies were counted and recorded as a percentage of the number used. That the mortality of the flies was the result of the sulfurous fumes and *not* of the carbon dioxide is indicated by the results of the following check test:

Table 1. — Comparative toxicity of gases for *Lucilia*.

Period of Exposure	Per Cent Moribund in	
	(1) Carbon dioxide	(2) Sulfur gases
5 minutes	0	10
10 minutes	0	22
20 minutes	5	32
30 minutes	6	44
45 minutes	17	78
60 minutes	22	92

An examination of figure 2 enables one to draw some interesting conclusions. First, it is obvious that the sulfur dioxide evolved is small in quantity, and that this quantity rapidly decreases. At its period of maximal increase the production of hydrogen sulfide falls. It is known that sulfur dioxide and hydrogen sulfide reduce each other: this is what happens in Wackenroder's solution as described by Debus. Evidently this is what happens in the production of gases from lime-sulfur, and since hydrogen sulfide is in excess, free sulfur dioxide soon ceases to appear. This explains why the mortality curve of the flies follows hydrogen sulfide production: hydrogen sulfide is the only gas present in a concentration sufficient to kill.—12-28-44.

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An Unusual Habit of The Pecan Budmoth in Florida

ARTHUR M. PHILLIPS, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

On November 6 and 7, 1944, while pecan shucks infested with the immature stages of the hickory shuckworm, *Laspeyresia caryana* (Fitch), were being collected, a large number of larvae and pupae of another insect were observed. These larvae and pupae were tentatively identified by the writer as the pecan budmoth, *Gretchena bolliana* (Sling.), and a number of them were collected and carried to the insectary for observation. Adult moths began to emerge November 9, and the previous identification was confirmed.[2]

It was noted that the budmoth larvae and pupae were between the shuck and nut, and that the pupae were webbed up in the opening between the sections of the shuck (Fig. 1). The frass in the webs around the pupae indicated that the larvae had fed on the shucks before pupating. This was also noted in later observations, and on December 4 one larva was found working inside the shuck.

The pecan shucks infested with the budmoth were still fairly green when collected, and were of the Waukeenah, Frotscher, and Moore varieties. About 3 bushels of these shucks were put in screened cages near the insectary for observations on emergence of moths.

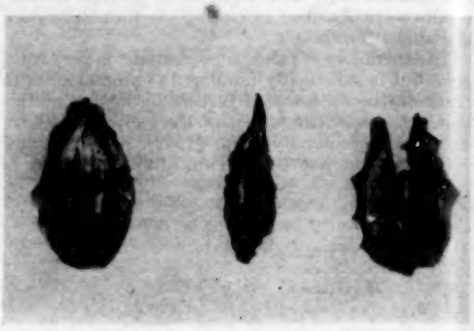

FIG. 1.—Larva and pupae of the pecan budmoth in pecan shucks.

The following record of emergence of the adult budmoths from the pecan shucks that were collected shows the period of emergence and also gives some idea of the intensity of the infestation:

1944	Number of Moths Emerged	1944	Number of Moths Emerged
Nov. 9	3	Dec. 8	1
10	3	11	8
13	2	15	10
14	4	16	27
16	22	19	30
17	6	20	11
18	5	21	10
20	15	22	11
21	8	23	6
22	12	27	34
23	23	28	5
24	10	29	14
25	8	30	10
27	11	1945	
28	10	Jan. 4	4
Dec. 1	4	6	1
2	2	Feb. 12	1
5	2	16	1
		Total	334

It is interesting to note that moths emerged throughout December even though the weather was unusually cold for this area. The minimum temperature for the month was 22.5° F. on December 15.

Because the pecan budmoth is considered to be primarily a bud feeder, it is assumed that this late brood of larvae migrated from the buds to the pecan nuts for some unusual reason, since a search of published literature has failed to reveal any previous records of such a migration, or of the pecan budmoth having been reared from pecan shucks.—8-3-45.

[1] In cooperation with the Florida Agricultural Experiment Station, Pecan Investigations Laboratory, Monticello, Fla.

[2] Identification was also later confirmed by Carl Heinrich of the Division of Insect Identification of this Bureau and J. R. Watson of the Florida Agricultural Experiment Station.

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Reemployment of Entomologists Returning from Military Service

The re-employment of entomologists who left their jobs to join the armed forces particularly concerns the men and women whose work was interrupted. It also greatly concerns the agencies which lost their services. The entomologists who engaged in the war effort represent all the fields of activity upon which the profession of economic entomology rests, ranging from the highly specialized work of the taxonomist to the duties of the plant quarantine inspector guarding our borders against the invasion of new insect pests. The part played by entomologists in the war, many of them for the first time being classified by the military as ENTOMOLOGISTS, is a well-deserved recognition of our profession and a source of satisfaction to all of us. In any consideration of reemployment of the veterans returning from military service, we cannot overlook the continued employment of those who remained at home and carried on under the stress of the war effort and the limitations of manpower and materials. The protection of our agricultural crops and the health and working ability of our rural labor from injury and loss by insects is a national problem of the first magnitude. There is need for entomologists in every state and federal agricultural agency and in industry to meet the demands for crop protection, since insect injury is the leading limiting factor in production.

To assist in the problem of reemployment of entomologists returning from military service, the following committee has been appointed: E. N. Cory, College Park, Md., Chairman; Roger C. Smith, Manhattan, Kans.; and L. M. Peairs, Morgantown, W. Va. To this committee has been assigned the large task of gathering and arranging information on the availability of entomologists returning from military service for reemployment, and on the demand for trained and experienced personnel. The cooperation of all interested in the continued welfare of the profession of economic entomology is enlisted.

D. L. VAN DINE

561,671,098,434 Reasons Why Your Journal Has Been Late

Readers of the JOURNAL have shown remarkable consideration in the matter of delays in the appearance of the issues of the JOURNAL during the war years and this consideration has been appreciated by the editor and by the publishers. While it is probably true that the editor has covered some of his own deficiencies under the blanket plea of "war conditions" in the printing business, it is still true that real difficulties were encountered by the printers. The following statement, prepared by Mr. Adolph J. Hyson, of the Geo. Banta Publishing Co., and printed in the shop magazine *Nightmare*, issued by the plant, gives some of the details which must convince all of us that the difficulties were very real. And, in addition, the matter is of great interest to any reader.

NOW IT CAN BE TOLD

A. J. HYSON

In the first days of the historic December of 1941, the Collegiate Press was a busy mid-Western printing plant engaged in the peaceable pursuit of manufacturing a diversified and more or less heterogeneous species of books and magazines. The Monday morning of December 8, however, saw the first signs of a change from peace-time printing to war-time

essentials which, as the war progressed, diverted approximately forty-seven per cent of our productive capacity into the channels of governmental "musts."

Unlike the great automotive plants, steel mills, and the hundred-and-one other manufactories about the country, which all saw drastic and complete change-over in machines and equipment, the Collegiate Press simply changed over to a manufacturing program of a different species of books—books with far from peace-time subject matter.

Before the echoes of the Pearl Harbor catastrophe had died down, we were beset with a series of countless headaches which are concomitant with any such abrupt transition. But these headaches had to be endured with patience, and the new work proceed as best and with what speed it might, for the word had gone out from Washington and from Annapolis that this or that book, in such and such quantities, had to be put on our presses—and *now!*

There was the big problem of paper availability which became progressively more difficult. There was the problem of man-power shortage which created plenty of headaches. Somehow or another the chain of obstacles was unlinked, one by one and slowly, and we saw the war-time printing program through to completion.

New titles, new books, were the order of the day. Navy men came to the plant to attend personally to the myriad minutiae inherent in the preparation of copy, the reading of galley and page proofs, the illustrations, paper, inks, cloth, etc. Once started, the cylinders of the presses and the machines of the bindery whirred ceaselessly. In brief, we were committed definitely and in a big way to our part in the war effort.

"What was your contribution to the war?" "What did you print, and how many books?" are questions frequently asked by the interested or the curious. The answer to the questions is the major purpose of this story of achievement. With the advent of V-J day we can tell the story, and the preceding paragraphs are but the preface to the statistics which will shortly follow.

It is obvious that so great a diversion of presswork and binding to war requirements had a very definite and direct reaction on our peace-time accounts and clientele. It was with sincere regret that we were compelled at times to disappoint some customer. New work, possible of acceptance with thanks during peace-time, had to be turned down—there just weren't enough man-hours, men and machines to take care of government demands.

Production plans and schedules were impossible of maintenance; a working schedule planned in the morning would be disrupted and changed through a directive or a priority plea by noon. And so it went; customers given a promise made in good faith were at times sadly disappointed—their work had to be delayed when war requirements demanded. The happy thought arising from remembrance of this turmoil is that at no time was a customer deeply disgruntled or impatient over a situation over which we had no control.

Altogether we printed 53 different titles for training purposes or instruction in the armed forces.

As the war progressed, the Army and Navy set up an intensive educational program for the men in service. This organization is known as "The United States Armed Forces Institute," and their publications came to be known as "USAFI" (yū-sà'fee) books. Topics treated in the series are mechanics, arithmetic, physics, mechanical drawing, foremanship, grammar, foreign languages, etc.

Some interesting figures may be arrived at by an analysis of the printing records. For example, the books which were printed for the navy alone represent the amazing total of 5,092,998, encompassing the astronomical number of 561,671,098,434 pages. Paper poundage was 6,805,651—3,400 tons, which would make up a train of 124 cars—almost one mile in length—each containing 55,000 pounds.

Paper consumption for the USAFI series: 3,068,672 pounds—4,728,204 books, 1,500 tons, a trainload of about 56 cars about one-half mile long.

That's the story of our part in the war effort, and the answer to the oft-asked questions "What did you print, and how much and for whom during the war?"

Office of Secretary and Business Manager
College Park, Maryland, October 6, 1945

The committee has sent out the following letter, with a suitable questionnaire, to members of the armed forces who may be interested. Prospective employers are invited to make use of the facilities of the Committee in filling vacancies.

"The principal objective of this committee is to assist entomologists who are or have been in the armed forces, Army, Navy, Marine Corps or the U. S. Public Health Service, to return to active entomological service. However, this committee will endeavor also to assist non-veterans in placement. It is realized that many expect to return to their former positions, but it is quite possible that others may desire to embark on new enterprises or begin with different associations. Most institutional employers have held positions open for returning service men, using temporary help or by putting additional loads upon those who remained. Under such circumstances, it was fortunate that in the teaching field, the paucity of students, a condition that will continue for several years, made possible shifts of emphasis. The Bureau of Entomology and Plant Quarantine, employs nearly half of the entomologists. Those wishing federal appointments should qualify for appointment with the Civil Service Commission. There is, as a result of the major role of insect borne disease control and the widespread publicity thereof, a greatly enhanced interest in all phases of insect control. Industry, for example, is keenly alive to the need for additional research and sales promotion and it has enlarged the scope of its endeavor. Agencies that heretofore have had little to do with insect control such as the U. S. Public Health Service, the Chemical Warfare Service and the Fish and Wildlife Service are capitalizing on the new materials and techniques developed during the war. Therefore, greater opportunities await the trained service man."

"This committee is sending the enclosed questionnaire to those needing its assistance and expects to announce its plans in the Journal of Economic Entomology so that employers and prospective employees may know of the activities of the committee and take advantage of the service that is being offered."

"From the questionnaires and other sources, notably the data in possession of the Committee on Military Entomology, a card file will be set up from which employers may secure the names and summarized qualifications of potential employees."

"Members of this association will be required to pay a fee of $1.00 for registration per year. Non-members who may wish to enroll will be required to pay a fee of $2.00. The Association is employing, on a part time basis, an entomologist who will have charge of the indexing and the selection of the entomologists to be submitted on the basis of their training, experience, skills and interests to prospective employers. In so far as possible, each prospective employer will be furnished with the names, references, and other information of as many registered entomologists as the records indicate as most nearly meeting the specifications of the employer seeking an employee."

"In order that this service may function, will you please return your questionnaire promptly whether you do or do not desire the services of this committee."

Very truly yours,
ROGER C. SMITH, ERNEST N. CORY
AND L. M. PEAIRS

UNINCLOSED BEE COLONY

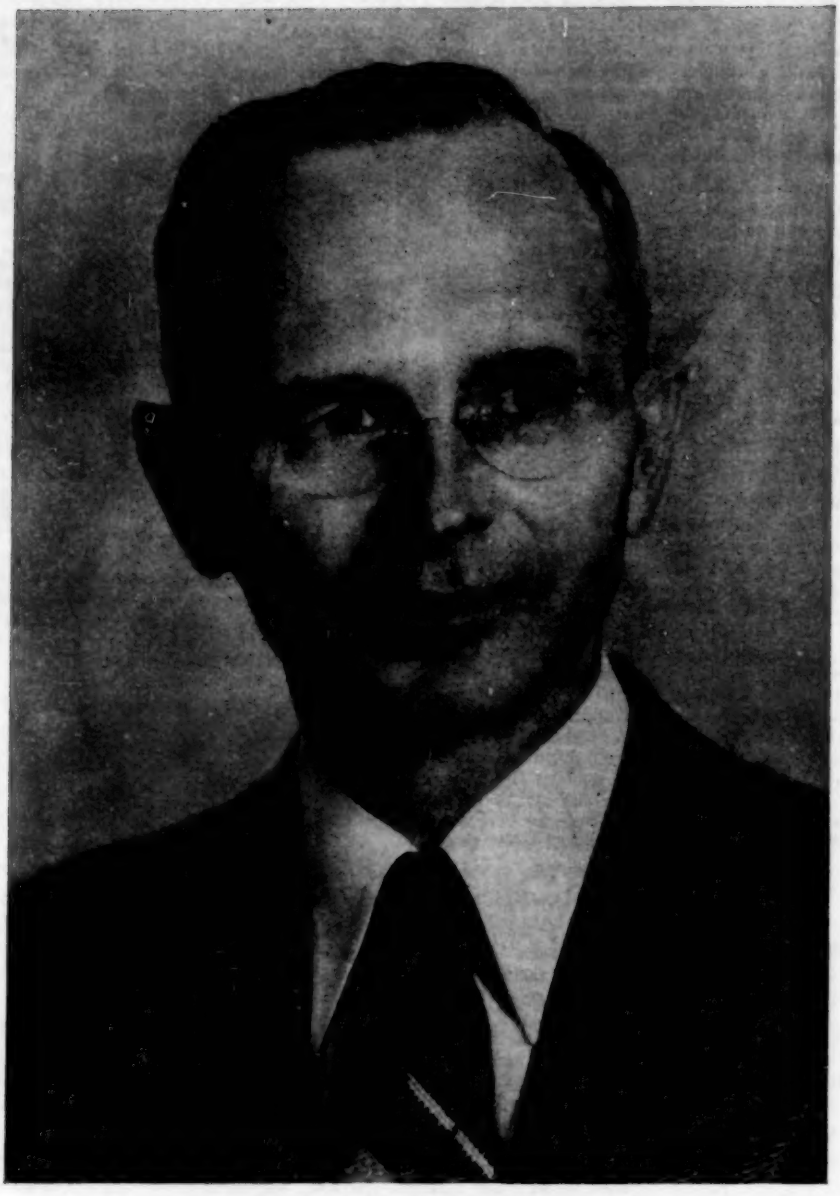
Located at an elevation of eleven-hundred fifty feet above sea level, twelve miles northwest of Clarksburg, on Peters run, Harrison county, West Virginia. Attached to a shell-bark hickory tree limb, parallel with and forty-five feet above the ground. Telescopic examination reveals that comb is attached only to under side of limb, at fork junction, twenty-five feet distant from bole.

The uninclosed bee edifice is composed of seven elongated discs of comb, and the entire structure will measure approximately fourteen by twenty inches. Each disc is fully two inches thick at center and is tapered to an outer feather-edge and, apparently, welded together on about a six-inch central mass. Space provided by the tapering disc design is fully occupied by bees. The visible area of completed cells disclose much space yet unfilled with honey. The comb discoloration is slight, perhaps indicating that the structure is of recent origin and has not withstood the test of an Allegheny mountain winter.

Progressing construction is on a series of fan-shaped, half-disc additions, attached to the ends of the structure and, when completed, will provide an uninterrupted circle of evenly spaced discs.

The colony was observed by Dr. H. H. Hanes and H. P. Sturm.

OBITUARY



Ralph Henry Smith, 1888–1945

Ralph Henry Smith was born on a farm at Kincaid, Anderson County, Kansas, June 7, 1888. He died at his home, 1634 Greenfield Avenue, Los Angeles, California, early Saturday Morning, September 22, 1945. His parents were pioneer farmers and he lived the usual rigorous life common to his times on the mid-western farm. He attended the country schools in Kincaid and spent two years at the Garnett High School after which he took the county examination for teachers, which he passed, and taught two terms in a country school before he was twenty years old. In 1908 he entered Kansas State Teachers' College at Emporia where he graduated in 1914. He taught for one year in the high school at Blue Rapids, Kansas and was Superintendent of Schools in Irving, Kansas, for the next two years. In 1915 he entered the University of Kansas and received the A.B. degree in the spring of 1916. In July of that year he received a teaching fellowship at the Oregon State College at Corvallis.

In 1917 he entered the University of California at Berkeley where he was a teaching fellow in Zoology and received his M.A. degree there in May, 1918. He was immediately sent by the Federal Government to take charge of a war emergency project on the control of clover aphis at Twin Falls, Idaho. At the end of the war the Idaho Agricultural Experiment Station took over the work and established a sub-station at Twin Falls with Mr. Smith in charge. The results of these investigations appeared in Research Bulletin No. 3, Idaho Agricultural Experiment Station, January, 1923, under the title: The Clover Aphis: Biology, Economic Relationships and Control. This bulletin was thorough in every detail and the illustrations set a high standard of excellence. He also began work on the control of codling moth at that time and stayed in Twin Falls until March, 1922. He then went to San Francisco and, while working as research entomologist for the California Central Creameries, he developed the casein spreader now so widely used in sprays. During the two years he worked on that project he continued the codling moth investigations and visited practically every state and all the important apple growing districts in the United States. In the fall of 1924 he reentered the University of California at Berkeley, completing the work on his Ph.D. in the spring of 1925. His doctor's thesis was "Studies with Freshly Hatched Larvae of the Codling Moth, *Carpocapsa pomonella* (Linn.) in Relation to the Efficacy of Lead Arsenate in Protecting Apples against Injury." In this thesis he set forth the idea that "the protective effect of any coverage varies directly with the poison concentration. The relatively high protectiveness of the spotted coverage, compared with the film coverage, is due to the thigmotactic response of larvae to thick edges of spray deposits."

He then accepted a position as Acting Assistant Professor in the Entomology Department at Stanford University during the fall and winter term of 1925–26. In March of 1926 he received an appointment as Assistant Entomologist in the University of California Citrus Experiment Station at Riverside and began work on oil sprays. During the 10 years he spent at Riverside he developed and perfected the tank mix oil spray, which has been used the world over. He was promoted to Associate Entomologist in 1927 and to Entomologist in 1931. He was also given the additional title of Lecturer in Entomology and Entomologist in the Experiment Station when transferred to the University of California at Los Angeles in 1936 where he was in charge of the entomological work on that Campus which was under the general supervision of Prof. H. J. Quayle and subsequently Dr. A. M. Boyce of the Division of Entomology, Citrus Experiment Station at Riverside. In 1937 he was advanced to Professor of Entomology. While at Riverside, he served on the City Board of Education and was particularly active in the development of better school facilities in that city.

Since that time he has investigated the insects affecting ornamental plants and devised means for their control.

During the past few years Dr. Smith made outstanding contributions in studies of the life history and control of the sycamore scale, *Stomacoccus platani* Ferris and the nigra scale, *Saissetia nigra* (Nietner). His surveys of the insects attacking flowering and greenhouse plants were very thoroughly and carefully made and his notes are of great value. He was also very much interested in plant-infesting mites and made extensive collections of these pests throughout the West.

In January, 1933 he was invited by the Citrus Growers of Texas to visit the Lower Rio Grande Valley and to advise them concerning especially the use of oil sprays for controlling red scale in that region.

At the time of his death he was conducting extensive experiments on the uses of the new insecticide, DDT, in the control of insect pests of ornamental plants. He was also preparing manuscripts for two books: one "The Insect Pests of Ornamental Plants in the United States" and the other: "The History of Oil Sprays."

Dr. Smith published very many articles in journals, bulletins, circulars and agricultural papers, all of which have constituted worthy contributions to science. In 1914, at Bonne Terre, Missouri, he was married to Sarah Fake, a fellow school teacher from Irving, Kansas, who survives him, along with four sons: Norman, Hamilton, Gordon, and Stanford. His mother, two brothers, and three sisters, all of whom live in Kansas and Oklahoma, also survive.

Although he was never a very strong man his ambitions and determination drove him to great heights of endeavor and he accomplished unbelievable results in many walks of life. His splendid character, high ideals, absolute honesty, and friendliness made him a man of great worth in his home life, in society, and in his profession.

E. O. ESSIG